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View of the Havel bridge during construction.

THE NEW BRIDGE OVER THE HAVEL, THAT OPENS UP MUCH TERRITORY FOR THE EXPANSION OF THE GERMAN CAPITAL.—[See page 228.]

The Future of Oil Fuel*

Depends on Increase of Output and Mode of Employment

By Sir Boverton Redwood, Bart., D.Sc.

The forecasting of the future of oil fuel in general is a complicated problem, the difficulty of which is commensurate with its interest and importance. To a large extent, the immediate future depends upon the evolution of the internal-combustion engine, and, as regards the mercantile marine, upon the measure of success attending the efforts to construct satisfactory engines of the Diesel type of large cylinder capacity.

In this connection, it must be borne in mind that the advent of the turbine engine, and the economies resulting from the use of superheated steam, together with other recent improvements in the efficiency of the steam engine, have rendered the task of the advocates of the internal-combustion engine more difficult. Moreover, the replacement of the turbine steam engine by the oil engine involves a return to the reciprocating type of machinery which is in itself a ground of objection as being in a sense a retrograde step, for at present there seems no prospect of the evolution of a successful turbine oil engine.

The progress of the petroleum industry during the years 1901–1912 is shown in the following table, and in illustration of the sensitiveness of the industry and of the precarious nature of the relation of supply to demand it should be stated that the falling-off in 1905 was entirely due to the interference with Russian oil-field operations caused by labor disputes, for during that year there was a considerable increase in the output of the American fields. The further decline in 1906 was contributed to by a smaller production in the United States.

Year	Metric tons.
1901 (Redwood and Eastlake)	22,160,701
1902 " " "	24,879,030
1903 " " "	26,285,270
1904 " " "	29,500,000
1905 (United States Report)	28,945,795
1906 " " "	28,643,410
1907 (Redwood and Eastlake)	35,729,238
1908 " " "	38,220,438
1909 " " "	40,070,832
1910 " " "	43,986,531
1911 " " "	46,431,404
1912 (David T. Day)	47,276,725

The chief sources from which the world's supplies of petroleum were obtained in the years 1911 and 1912, and the quantities which they respectively contributed are specified in the following tables:

WORLD'S PRODUCTION OF PETROLEUM IN 1911.
(Redwood and Eastlake).

Country.		Quantity. Metric tons.	Percentage of total.
United States—			
Appalachian field	3,166,644		
Lima-Indiana field	830,821		
Illinois	4,175,605		
Mid-Continent field	8,789,038		
Gulf	1,557,008		
California	10,817,918		
Other fields	56,215		
		29,393,249	63.305
Russia		9,032,532	19.453
Mexico		1,873,547	4.035
Eastern Archipelago		1,624,301	3.498
Roumania		1,544,072	3.325
Galicia		1,462,940	3.151
British India		850,065	1.831
Japan	220,673		
Formosa	218		
		220,891	0.476
Peru		186,405	0.401
Germany		142,992	0.308
Canada		39,743	0.086
Italy		10,390	0.022
Hungary		3,000[1]	0.007
Other countries, including Egypt and Trinidad		47,277[1]	0.102
Total		46,431,404	100.000

WORLD'S PRODUCTION OF PETROLEUM IN 1912.
(David T. Day).

Country.	Quantity. Metric tons.	Percentage of total.
United States	29,615,096	63.25
Russia	9,317,700	19.37
Mexico	2,207,762	4.71
Dutch East Indies	1,478,132	3.09
Roumania	1,806,942	3.70
Galicia	1,187,007	2.43
India	980,801	2.03
Japan	222,854	0.48
Peru	233,486	0.50
Germany	140,000[1]	0.28
Canada	32,612	0.07
Italy	12,000[1]	0.02
Other countries	33,333	0.07
Total	47,276,725	100.00

In estimating the relative importance of the various sources, it is necessary to take into account the ever-varying factor of the quality of the crude oil as governing the proportion of the various products obtainable. Not only does the oil of one country differ from that of another country, but in the same country we find many different descriptions of oil, sometimes in the same district, and even in the same spot the oil obtained at depth may present no similarity to that found nearer the surface. Cases have occurred in which the deeper strata, where the oil is more effectively protected against loss by fractional evaporation, have yielded a product containing many times the percentage of motor spirit present in the oil from the upper strata. The matter is further complicated by the continuous shifting of the chief centers of production from one country to another, or from one field to another in the same country. Thus, at the present time, oil is being imported from Mexico into Russia.

THE DIESEL MARINE ENGINE.

The principal feature of the oil-carrying trade of the Caspian Sea during the past few years has been the growth in the substitution of the Diesel engine for the steam engine as the motive power of the vessels employed. This has arisen from the far greater economy in fuel consumption of the Diesel engine system, for whereas the consumption of oil fuel for steam raising amounted to from 3 per cent to 3.4 per cent of the oil carried from Baku to Astrakan in 1912, the Diesel engine consumption is stated to have been only ½ per cent.

The decline in the Russian oil output has been mainly due to the falling off in the production of the small area in the Baku region, on which the drilling operations have been largely concentrated.

Apart from the possibility of such modifications of the present method of carbonizing coal as would render an additional quantity of liquid products available for use as fuel, to which further reference will be made, an increased quantity of oil fuel could be obtained from Scottish shale, and very large supplies from the far more extensive deposits of similar shale which occur in France, Servia, Spain, the United States, South America, New South Wales, New Zealand, New Brunswick, Nova Scotia, Newfoundland, and elsewhere. It may also be found possible to utilize the bituminous clay or Kimmeridge shale of Dorsetshire as a source of oil fuel.

CONSUMPTION OF MOTOR SPIRIT.

In Great Britain alone the consumption of motor spirit, which in 1905 was only about 18,000,000 gallons, has increased to not far short of 100,000,000 gallons, the imports last year amounting to about 80,000,000 gallons. Of these imports, 46,000,000 gallons came from the Dutch East Indies, and 16,000,000 gallons from the United States. It is true that if we take the average proportion of motor spirit obtainable from the crude oil at 10 per cent, the amount imported last year represents only about 2½ per cent of the world's production of this product, but it is a significant fact that whereas a few years ago the United States supplied the world, we only obtained from that country last year one fifth of the quantity we required, and, with the rapid growth in the American home consumption, the export trade may soon reach the vanishing point.

Already, in fact, considerable quantities of motor spirit have been imported from the Dutch East Indies into the United States, and the utilization of the bituminous shales of the latter country as an additional source of mineral oils is being discussed.

The present situation is mainly due to the circumstance that the use of motor spirit in road vehicles has increased with startling rapidity—at a rate, indeed, which is presumably far greater than was foreseen by few, if any, of those responsible for the supplies of the fuel. In the United States alone the number of cars in use increased from 15,000 in 1902 to 590,000 in 1912, while the output of gasoline in that country increased from 6,600,381 barrels to about 13,000,000 in the same period. Therefore, the number of vehicles using gasoline had increased forty-fold, while the production of the fuel had only doubled.

THE "CRACKING" PROCESS.

Attention is being directed to the conversion of the heavy oil into motor spirit by the operation of "cracking," or dissociation. This process was placed upon a scientific basis by the classical researches of Thorpe and Young, who showed in 1871 that by action of heat under pressure solid paraffin is converted into hydrocarbons (paraffins and olefines), which are liquid at ordinary temperature.

In one of the latest applications of the principle of "cracking" a suitable heavy oil and water are brought into contact with a large surface of iron or other metal in highly-heated retorts, and in these circumstances a considerable proportion of the oil becomes converted into excellent motor spirit.

A difficulty in connection with the increase in the output of motor spirit is that the average crude oil only yields a comparatively small percentage of a product of the desired volatility, and that an outlet must be obtained for all other products. For many years past, the consumption of kerosene as an illuminating agent has been diminishing rather than increasing, and there has been keen competition among sellers, with concurrent reduction in the price obtained, and although the larger domestic use of petroleum stoves for heating and cooking has, to some extent, arrested the diminution of the burning-oil demand, the difficulty has been acutely felt. Public-service motor vehicles are now being driven in this country with a mixture of gasoline and kerosene, and the latter product can be used alone with a suitable carbureter if the engine is started with gasoline, which can be supplied from a small auxiliary tank, but the private consumer is justifiably reluctant to use kerosene as long as he can obtain motor spirit, even at an enhanced cost, for it is more difficult to get satisfactory combustion with the heavier fuel, and in crowded streets there would probably be serious complaints of the character of the exhaust. Apart from this, it seems almost impossible to prevent the kerosene from gradually rendering not only the chassis, but even the interior of the vehicle unpleasantly oily and odoriferous.

The oil fuel which is chiefly used in steam raising is a product of a very different character. Crude petroleum of a low flash-point is largely used as a fuel in steam raising in the oil fields, but the oil fuel of commerce is usually required to be of comparatively high flash-point, and is either a distillate or more commonly the residue of crude petroleum from which the more volatile constituents have been removed by fractional distillation.

In the British mercantile marine the minimum flash-point is 150 deg. Fahr. (Abel test), while in the United States it is 140 deg. Fahr. by the Abel-Pensky or Pensky-Martens test, and in Russia, Roumania, and Germany it is 80 deg. Cent. (176 deg. Fahr.).

BURNERS FOR OIL FUEL.

For the use of such oil in steam raising, various systems have been, from time to time, patented. One of the simplest devices is the burner of Nobel, which consists of a number of shallow troughs, arranged in superimposed series at the front of the furnace, so that the burning oil flows by successive stages from the highest to the lowest, the flame of the burning fuel being swept into the furnace by induced draft passing between the troughs. With this apparatus, it was found that 1 pound of Russian ostatki (petroleum residuum) evaporated 14½ pounds of water, whereas with the same boiler 1 pound of coal evaporated only 7 pounds of water.

The Wallsend Slipway & Engineering Company's burner has a nozzle with a conical orifice, from which the heated oil, under a pressure of 60 to 80 pounds per square inch, issues as a spray in the form of a conoidal column of large diameter, with a rotary movement imparted by a helix on the valve stem, the resulting centrifugal effect materially assisting in the conoidal diffusion.

The improved construction of the furnace front is the principal feature of the Wallsend-Howden system of oil burning as applied to marine boilers. Each of the oil-splaying nozzles projects through a baffle plate, or the front plate of the casing, into an air trunk having lateral openings at its outer end. This air trunk projects concentrically with a second air trunk carried by the furnace front, and the annular space between the inner and outer air trunks is fitted with deflectors constructed in such manner as to give the air passing through the annular space a spiral motion. One advantage of this arrangement is that the openings for the supply of air are so disposed that direct radiation of heat from the furnace is prevented. When used with forced draft on Howden's system, with closed furnace front, an efficiency as high as 16.22 pounds of water evaporated from and at 212 deg. Fahr. is claimed to have been obtained per pound of oil of a calorific value of 18,770 British thermal units, an efficiency of 83.9 per cent.

MERITS OF OIL FUEL.

A lengthy experimental investigation of the merits of oil fuel was carried out by the United States Naval Liquid Fuel Board in 1902–3. Many forms of burner were tested, and the results obtained led the Board to the conclusion that the actual evaporative efficiency of a pound of oil as compared with a pound of coal might be considered to be in the ratio of 17 to 10, but that, taking various circumstances into consideration, the

*Abstract of presidential address to the Junior Institution of Engineers, published in *Shipbuilding and Shipping Record*.

[1] Estimated.

relative efficiency of oil and good steam coal from the naval standpoint of fuel supply in warships, might be regarded as in the ratio of 18 to 10.

In the use of oil fuel, the construction of the furnace is of the highest importance, for it is needful that the combustion should reach an advanced stage before the flame comes into contact with cooling surfaces. It will readily be understood that, with the limited furnace space available in steamships, and especially in warships, it was exceptionally difficult to devise conditions under which smokeless combustion could be obtained. The difficulty has been overcome by the adoption of a form of burner which gives a spreading flame commencing close to the jet, and by heating the oil, but chiefly by the provision of an effective air-heating furnace front.

The substitution of oil fuel for coal in steam raising is, however, a wasteful method of using this source of power, for whereas we do not ordinarily obtain with the steam engine more than 12 per cent of the energy of the fuel in the form of work, in the case of the Diesel engine the return is as much as 37 per cent. Unfortunately, the difficulties attaching to the construction of engines of this type with large cylinders are great, but so much attention is now being given to the subject by engineers of the highest eminence that it may be confidently anticipated that the difficulties will be overcome. Meanwhile, the use of the Diesel engine of moderately high power on land is making steady progress, and much has already been accomplished in its application to marine work. The experience gained with such vessels as the "Selandia" and "Jutlandia" led to arrangements being made for the installation of Diesel engines in many other cargo boats, and it has been demonstrated that the fuel consumption is between 0.4 pound and 0.46 pound per B.H.P.

The high thermal efficiency of the Diesel engine is due to the adoption of the principle of injecting the charge of oil into the air after compressing the latter, instead of mixing the oil and air and compressing the mixture, for the efficiency is proportionate to the extent of compression, and in internal-combustion engines of the ordinary type the risk of premature spontaneous ignition prevents the use of high compression. In the Diesel engine, a pressure of as much as 32 atmospheres can be employed, and almost any description of mineral oil introduced in proper quantity into it at the moment of the completion of the pressure stroke is at once completely and most effectively consumed.

OIL AND MARINE PROPULSION.

It is in the provision of power in ships that the superiority of the oil engine over the steam engine is most marked, for, apart from the economy, there are great advantages in the saving of space, the distance which can be covered without replenishing the fuel supply, the reduction in labor, and the facility with which the oil can be taken on board; moreover, the engine can be started without previous preparation, and the consumption of fuel arrested equally quick.

Some of these advantages attach to the use of oil as a substitute for coal, or even as an adjunct to coal, in warships, and to these may be added the valuable capacity for rapidly increasing the production of steam. In commenting upon the advantages of oil fuel, as demonstrated in the naval maneuvers carried out under Admiral May in 1906, Admiral the Hon. Sir E. K. Freemantle said: "When the stokers were pretty well worn out and had used all the coal that was nearest at hand, and much labor would be necessary to fetch coal and bring it to the fires, then they were able to use the oil fuel, and I believe I am correct in saying that the four ships which had oil fuel steamed away even from ships with nominally greater speed."

On the initiation of the late Lord Furness, the cargo boats, the "Eavestone" and the "Saltburn," were built and equipped respectively with oil engines and steam engines in order to furnish a practical comparison of the two systems of propulsion. The former vessel was fitted with a set of Carel-Westgarth two-stroke cycle Diesel engines, and the latter with triple-expansion engines. Both vessels are 276 feet in length between perpendiculars and 40 feet 6 inches beam, and are otherwise similar. The capacity for fuel oil in the double bottom of the "Eavestone" is 156 tons, and the capacity of the coal bunkers of the "Saltburn" is 380 tons. The Diesel engines of the former vessel have four single-acting cylinders 20 inches in diameter by 36-inch stroke working upon the 2-stroke cycle at 96 revolutions per minute. The high-pressure and low-pressure air compressors are worked direct from the main engine; the high-pressure compressor for injecting the fuel oil being one of Reavell's patent three-stage compressors fitted at the forward end of the crank-shaft; the low-pressure is provided by two ordinary compressors worked by levers at the back of the main engines; the pumps for circulating water for the jackets, the bilges, and the oil-supply pump, etc., are also worked in the same way. There is an auxiliary Reavell air compressor for starting up and as a standby, which, together with the ballast pump and other auxiliaries, is steam-driven, and the necessary complement of air receivers, oil filters, etc., is provided. The winches, steering gear, etc., are the same as those of the "Saltburn," and as steam is required at sea for the steering gear and whistle, and for heating the cabins, two auxiliary boilers, each 7 feet diameter by 14 feet high, and 100-pounds pressure, have been fitted, together with a "Contraflo" auxiliary condenser, and a small Morison evaporator. Either boiler is capable of doing the work, and only one is under steam at sea. Arrangements have been made to drive the steering gear by compressed air from the main-engine compressor, and this has been found so satisfactory that air is always used when at sea.

The "Saltburn" engines have cylinders 20½ inches, 33 inches and 54 inches by 36 inches running at 62 revolutions per minute, with two single-ended boilers, 13 feet in diameter by 10 feet 6 inches long, and 180 pounds working pressure, the engines being fitted with an ordinary surface condenser, Morison feed heater and evaporator. There is the usual outfit of steam winches, steering gear, etc., and one auxiliary boiler, 7 feet in diameter by 14 feet high, and 100 pounds pressure.

COMPARATIVE TRIALS OF THE "SALTBURN" AND "EAVESTONE."

The working results, based on five voyages of each ship, showed that the "Eavestone" had an average speed of 8.75 knots with an oil consumption of 3.64 tons per day, and a coal consumption of 13 hundred weight per day in the auxiliary boilers; while the speed of the "Saltburn" was 8.4 knots with a consumption of 12.1 tons. The deadweight capacity of the Diesel-engine ship is only 20 tons more than that of the other vessel, which is accounted for by the extra weight which it was thought wise to put into the first engine of this type, and by the additional auxiliary boiler. It is anticipated that this weight can be considerably reduced, especially, if the auxiliary boilers are dispensed with and the auxiliary machinery driven by electricity or compressed air. The chief saving in weight, however, is in the smaller quantity of fuel to be carried for the Diesel engine. Thus, if both ships were loaded for a 30 days' voyage to be made at the same speed, the "Saltburn" would have to ship 405 tons of coal, while the "Eavestone" would take only 110 tons of oil fuel and 20 tons of coal for the auxiliary boiler, a total of 130 tons, or 275 tons less than the steamship, and consequently the Diesel ship could carry that extra weight of paying cargo. The cost of the crew is in favor of the Diesel ship, as no firemen are required. On the other hand, the cost of the Diesel engine is more than that of the steam engine. The foregoing particulars appeared in an article in "Cassier's Magazine," by Mr. T. Westgarth.

ADVANTAGES AND DISADVANTAGES OF THE DIESEL ENGINE.

In the same journal, Engineer Lieut. W. P. Sillence, R.N., discusses the advantages and disadvantages of the marine Diesel engine, and expresses his views as to the probable lines of development. He anticipates the extended use of this means of propulsion for tank steamers employed in the transport of oil fuel in bulk, and for cargo vessels in general when supplies of oil fuel can be obtained at a sufficiently low price. On the subject of price, he points out that, taking triple-expansion steam engines using about 1½ to 1¾ pounds of coal per I.H.P. per hour, and Diesel engines using, say, ½ pound of oil per B.H.P. per hour, the cost of fuel per hour for the same B.H.P. would be less for the Diesel engine, even if the oil is 3½ times to 4 times the price of coal. The relative prices are much more favorable than this in many parts of the world, and in many steam engines, the consumption figures given above should be doubled. On the other hand, he considers that the early adoption of Diesel propelling engines for the largest ocean passenger liners is unlikely, as much preliminary experimental work will be necessary, and he adds that "a serious question, viz: continuity of supply and stability of prices of suitable fuel, remains to be answered." He is, however, emphatically in favor of the employment of Diesel engines for auxiliary purposes in large mercantile vessels, the auxiliaries to be electrically driven, and the current generated by Diesel engines placed in a central dynamo room. On the subject of Diesel engines, for naval service, he points out that naval vessels are not maintained in commission in order to earn money, and that Diesel engines, if they could be installed, would secure for such ships a large reduction in the amount of fuel used at any speed, and a corresponding increased radius of action for the same total weight of fuel carried. Diesel engines, he adds, for use at cruising speeds will maintain a high economy at such speeds, and Diesel engines for auxiliary purposes will enable the ships to use electric light and power in harbor with a minimum of attendance, and with considerable economy, due to their independence of boilers. For reasons which he gives, he states that the propulsion at full speed of torpedo-boat destroyers by means of Diesel engines is not practicable, but he regards the Diesel engine as an ideal source of power for submarines.

THE FUTURE OF OIL FUEL.

It is, therefore, evident that the future of oil fuel depends not only upon the extent to which it is reasonable to assume that the output can be increased, but largely upon the manner in which the fuel is used, for in the light of our present knowledge it would obviously be wrong to suggest that the supply can ever become so abundant as to give consumers in general a free choice in substituting oil for coal as a source of power for industrial purposes, especially if the oil is not used in the most economical manner. The petroleum industry is one of great magnitude and importance; it never has been in a more vigorous condition than it is in to-day; it is unquestionably capable of much further expansion, and the use of it as fuel will undoubtedly largely increase; but although it is impossible to say what further stores of petroleum remain to be discovered, it is evident that it will require a very considerable expenditure of capital to greatly increase the average rate of expansion of the petroleum industry, especially as some of the older oil-fields are showing signs of exhaustion.

What may be the position even in the immediate future, it is impossible to predict with any approach to precision, owing to the uncertainty of the factors. There will doubtless be a continuous and large increase in the requirements of the navies of the world, and as this demand is not primarily governed by price, it may be described as irresistibly preferential in character, taking precedence therefore over all industrial needs. Further rapid progress may also be expected in the use of the more volatile products in road motor vehicles, and in some countries favorably situated in respect of supplies there will doubtless be a greatly extended employment of oil fuel on railways. In respect, however, to the general substitution of oil for coal as a source of power in industrial establishments on land, it does not seem reasonable to anticipate more than the adoption of the former fuel to the limited extent commensurate with a gradual increase in the output, and with the surplus available after other demands have been satisfied. There will, therefore, be competition among consumers to obtain supplies, and as regards stationary sources of power it is improbable that, excluding exceptional cases, the oil will be used otherwise than in an engine of the Diesel or semi-Diesel type. The latter type of engine is receiving special attention in this country, whereas on the Continent it has been neglected for the Diesel engine, and it should be remembered that the former is somewhat less economical in consumption and more exacting as to quality of fuel than the latter, the consumption of oil per B.H.P. hour being about 0.6 pound.

Except as regards the belligerent navies of the world, in respect of which the dominant factor is efficiency, it is evident that any increased use of oil as a source of power must depend upon the price at which the fuel can be obtained. In the use of oil for steam raising, and in other industrial operations, the consumer can afford to pay about twice as much for oil as he pays for coal, in view of the higher thermal efficiency of oil and other advantages attaching to its use, but if the market value of oil fuel becomes established on what may be termed the Diesel-engine basis, it is only those who occupy exceptionally favorable geographical positions in respect to sources of supply who could hope to employ that description of fuel in steam raising.

The Rôle of Fluorine in Animals

For more than a century past the existence of fluorine had been known in the teeth and bones. Taking up these researches with M. Clausmann, M. Armand Gautier established in 1912 that fluorine is spread through all the organs of animals, but in very different proportions. There are 190 milligrammes in the enamel of the teeth and 0.750 milligramme in the muscles. What is the rôle of this very active substance? MM. Gautier and Clausmann have established the fact that fluorine accompanies phosphorus everywhere, without, however, being proportional to it. Analyses made of the white and yellow of egg, of different milks, of the blood of carnivorous animals and herbivorous animals show that fluorine and phosphorus increase and decrease together. In the noble tissues of intense life, the brain, liver, pancreas, it is found that one part of fluorine suffices to bind 450 to 750 parts of phosphorus. In the hard tissues of life—bones, cartilages—one part of fluorine binds on an average only 150 times its weight of phosphorus. In the tissues of products of excretion, products of mechanical defense, or of ornamentation, such as hair, nails, feathers, epidermis, the fluorine retains only 3.5 or seven parts of phosphorus. Henceforth having become unfit for life, the fluorine is thrown off by the fall of the hair, down or epidermis. Thus the accumulation of fluorine in these products, which in themselves are not inherent to life, are destined to be thrown out.
—*Chemical News.*

Many of the forest fires attributed to railroads are caused not by sparks from locomotives, but by cigar and cigarette butts thrown from smoking-car windows.

Erection of the superstructure of the center span of the new Havel bridge.

The New Havel Bridge, Berlin

Opening Up the Territory Across the Havel for the Expansion of the German Capital

By C. Van Langendonck

THE bridging of the Havel Valley marks an epoch in the development of Greater Berlin inasmuch as it accomplishes the opening up of the land situated to the west of the Havel. The bridging of this valley is also of technical significance on account of the great width of the Havel Valley and the extremely bad soil conditions.

This important engineering problem has been solved satisfactorily both from practical and aesthetic standpoints. The work involved the building of two bridges, the Havel Bridge and the Stossensee Bridge, and also of a dam. The total cost of the whole enterprise amounted to $635,000. The following article is concerned solely with the building of the Havel Bridge.

The Havel Bridge has a width of 78 feet 9 inches and a total length of 537 feet $4\frac{3}{8}$ inches. The bridge has five spans. Their respective lengths are as follows: End spans, 61 feet $11\frac{7}{8}$ inches; side spans, 107 feet $4\frac{5}{8}$ inches and 99 feet 3 inches, and middle span 206 feet $7\frac{3}{4}$ inches.

Since boats are to pass under the bridge, there is necessary a vertical clearance of 13 feet at high water. The thickness of the floor must, on that account, be the minimum, so that in the center span, bridging the stream with the two tow-paths, the main trusses of 206 feet $7\frac{3}{4}$ inches could not be placed beneath the floor. They are accordingly overhead trusses, one on each side of the roadway, which is 52 feet 6 inches wide. This makes the distance between them no less than 57 feet $8\frac{3}{4}$ inches, and as the result of this separation the floor of the bridge is $6\frac{1}{2}$ feet thick. Furthermore, the fact that it was necessary to go down through about 26 feet of bog before reaching a satisfactory foundation bed made it advisable to extend the bridge beyond either bank, far enough to bring the abutments out of the marsh as much as possible. For aesthetic and practical reasons, and no less for the sake of furthering traffic, the trusses in the side spans were placed below the roadway, but never to the exclusion of the possible construction of streets, under the side arches, should the future demand it.

On account of the necessity of going so deep before reaching solid bottom, a statically determinate structure was chosen for the bridge. The bearings are all on the same level, which means that the main trusses on the right hand side are the higher. The trusses of the middle span cantilever into the side spans, as do those of the end spans; so that in the side openings small trusses are suspended on the ends of the cantilever trusses. The bridge does not cross the Havel at right angles, and since the piers stand parallel to the banks, the two main trusses of the middle span, separated as they are by a distance of 57 feet $8\frac{3}{4}$ inches, are displaced with reference to one another by 8 feet $1\frac{5}{8}$ inches. In order not to carry this inequality over into the side spans, and to keep the end piers at right angles to the long axis of the bridge, the cantilever arms on the main trusses are made of such different lengths that the transverse girders which join the ends of the cantilevers run at right angles to the long axis of the bridge. In each side span four main trusses are used. These are so arranged that the outermost ones form a continuation of the main trusses of the middle span while the inner ones are separated from these by a distance of 19 feet $10\frac{7}{8}$ inches; their distance from one another being 17 feet $10\frac{7}{8}$ inches. The end transverse girders of the cantilever arms are built heavy enough for these inner trusses to rest directly upon them. In the whole super-structure, there is but one fixed bearing, and that is on the down-stream side of the main truss.

All the other bearings allow of motion in three directions: lengthwise, from side to side, and diagonally. The hinges can transmit forces in the direction of the long axis of the bridge. The middle span consists of a two-hinged arch whose thrust is taken by a horizontal tie, which is attached to the first joint of the bottom chord. This is given such a camber that it runs parallel to the road surface between joints 2 and 18. The arch itself has a height of 14 feet $3\frac{1}{4}$ inches over the two bearings, and in the middle a height of 5 feet 3 inches, so that the proportion is

$$\frac{\text{height of arch}}{\text{span}} = \frac{1}{39.4}$$

The rise of the bottom chord is 34 feet 8 inches, that is 1/5.9 of the span.

The heights of the trusses in the side spans were conditioned by the thickness of the bridge floor, which had to be kept as low as possible, in order not to obstruct the view, and to facilitate the building of streets along the banks, etc. Underneath the roadway, the main trusses are connected by lateral struts. The rigidity of the trusses is, for this reason, reinforced by strong bracings to prevent lateral buckling. The difference in span of the main trusses of the side openings is the result of the displacement of the piers of the middle span. The transverse girder which connects the ends of the cantilever arms is 20 feet 8 inches distant from the middle of the oblique transverse girder between the bearings. This distance has been made equal to the distance between all the transverse girders. The span of 206 feet $7\frac{3}{4}$ inches is divided into ten equal fields. The main trusses of the middle span have therefore on one side a cantilever arm of 20 feet 8 inches — 4 feet $\frac{3}{4}$ inch = 16 feet $7\frac{1}{4}$ inches; on the other side one of 20 feet 8 inches + 4 feet $\frac{3}{4}$ inch = 24 feet $8\frac{3}{4}$ inches. The cantilever arms of the main trusses over the end spans have also a length of 20 feet 8 inches, so that the suspended trusses of the side openings have a span of 61 feet $11\frac{7}{8}$ inches.

The outline of the arches is so drawn as to make the chords form a catenary, determined by a series of simple loads. As a result of the displacement of the two middle piers, the cantenaries of the two half arches are unlike. The lower chords of the outermost openings are assymmetrical. The purpose of this somewhat complicated arrangement of the super-structure, made up as it is of a combination of oblique and straight spans, was to adapt the finished supporting framework as naturally as possible to the given structural demands, not to erect an ugly iron structure merely for the sake of greater ease in planning or construction. Lateral rigidity in the middle span is obtained by means of transverse bracings in the planes of the verticals, which brace themselves horizontally against a simple lattice-work lying in the plane of the lower chord of the transverse girders. In the side spans, an outer main truss is connected to an inner one by a tie lying at the level of the lower chord. This tie makes with the cantilever a K-formation. In the suspended trusses, the spaces in which the pipes run are left free from ties on account of the lack of height and the easier installation of the pipes. In the first and fourth interspaces run lattice-work ties. Finally there is still another tie between the first and second longitudinal girders of the sidewalk which gives lateral rigidity to the upper chord of the side spans.

The building of the piers was accomplished by means of caissons. The super-imposed masonry of the piers is faced with clinker, the inner portion being of concrete. The piers for the main trusses of the middle span consist of two separate piers on account of being so widely separated. The adjacent piers, since they must carry four trusses each, are made up of four separate piers braced at grade level by re-inforced concrete beams and resting on a continuous foundation. Conveniently disposed to the roadway at the end piers are flights of stairs.

Concerning the super-structure, it may be mentioned that the roadway is carried by steel sleepers, laid at a distance of $13\frac{3}{4}$ inches from one another. Between these are laid tiles similar to roofing tiles, and the interstices are filled up with Bims concrete, in the effort to get a light roadway. Over the smooth surface thus obtained is spread a layer of cement averaging $\frac{5}{8}$ of an inch in thickness, on which tektolith has been pounded down. The thickness of this cement layer is carefully graded to give exactly the desired profile to the roadway, which is finished by a wood pavement 5 inches thick. At a distance of 20 inches from the curbing, the wooden pavement has a pitch of 1:15, the remaining portion presents a parabolic curve. For the sidewalk, Monier slabs $2\frac{3}{8}$ inches thick with an asphalt covering $1\frac{3}{16}$ inches thick were used.

In the middle span and the two eastern spans, the super-structure was erected on solid scaffolding, while that in the two western spans, on account of its lesser height, required none. The scaffolding for the middle span consisted of round piles which were driven $6\frac{1}{2}$ feet into the ground. For shipping, two passageways were left of a clear width of 31 feet. The scaffolding of the eastern openings was built of wooden struts with caps and sills and corresponding keyed connections. The whole scaffolding was 85 feet broad, and on both sides were tracks for the construction crane which were extended still farther over the two western openings on special wooden trestles. This crane had a span of 85 feet $3\frac{5}{8}$ inches and a clear height of 36 feet 1 inch above the rails, and could reach any point of the structure.

Two electrically driven cranes, each of 12 tons carrying power, were used to lift and place the various members of the structure. The riveting of the whole superstructure, which when finished weighed 16,000 tons, was done by compressed air.

Concerning the testing of the bridge, the following should be said: The test of the middle span was made before the covering of the roadway was in place, in order to measure the vertical deflection and the transverse displacement of the crown of the arch, the displacement of the bearings and the tension in the tie, and to compare these results with the figures already obtained by calculation. The test load corresponded to an evenly distributed traffic load of 500 kilogrammes to the square meter. The greatest strain on a main truss occurs when roadway and one sidewalk are carrying the load. In order to use as small an amount of gravel as possible for the test load, only the five middle fields were loaded, each with 77 kilogrammes to the square meter, in order to obtain the same tension in the tie as would result from a load of 500 kilogrammes on the entire middle span. As shown, the greatest displacement of the movable bearings is 3/8 inch and 1/4 inch respectively. The lateral displacement of the crown of the arch was measured after the roadway alone was loaded, since the loading of the sidewalks would tend partially to counterbalance this displacement. The test gave an inward displacement for each crown of 14/32 of an inch, in comparison with the 15/32 calculated. The results of the measurements of stress were also satisfactory. The stresses in the tie were 317 and 221 respectively, while the calculations had amounted to 325 and 227 respectively.

Preventing the Waste of Oil and Gas from Flowing Wells

The United States Bureau of Mines is conducting a series of investigations with the common aim of minimizing the losses that generally accompany the mining of the country's mineral resources. The results of these investigations are being recorded in various publications of the Bureau. The present article, which is an extract from a paper written for the Bureau of Mines by Ralph Arnold and V. R. Garfias, covers a description of certain methods of preventing some of the waste incident to oil mining.

Methods for the prevention of the tremendous waste that usually accompanies the "coming in" of wells producing large quantities of oil or gas by natural flow fall naturally into two classes, preventive and remedial. The first have to do with keeping under control whatever gas or oil may be encountered in the process of drilling; the second relate to the capping or subduing of wells "blown out" or "gone wild."

Before considering these methods, however, it is well to note the following general conditions affecting flowing gas and oil wells, especially in California, for they have an important bearing on the success of either class of operations:

1. The gas from "gassers" and the gas that generally accompanies the oil is not injurious to health, hence workmen without being harmed may labor near the well.
2. Owing to the tremendous velocity of the stream of gas, the part immediately over the casing head is like a smooth column, and may be approached with safety.
3. The sand, usually expelled under tremendous force with the oil or gas, often wears out the casings, but this wearing action generally takes place only throughout the uppermost 30 or 40 feet and opposite or near the place where the gas enters the well, thus leaving the main part of the entire length of the strings practically sound.
4. The great volume and tremendous pressure of the gas and oil make the use of the best fittings a necessity. Some of these, being of special sizes, are made to order.

For convenience, and in accordance with common usage, the flowing oil wells and the gas wells are designated respectively as "gushers" and "gassers."

PREVENTIVE MEASURES.

With the present state of our knowledge regarding the situation of the "gusher" and "gasser" strata in the developed fields, there is no excuse for the general lack of precautions taken before the depth is reached at which the flow is expected. Furthermore, if the well is being drilled in a new or prospective field, adequate precautions should be taken so as not to jeopardize in advance the possible profits of such an uncertain and expensive undertaking. The additional cost of the safety devices is insignificant in comparison with the total cost of drilling such wells and with the amount that can usually be saved if their rate of production is regulated. It may be safely stated that practically all of the great waste resulting from the unrestricted flow of gassers and gushers can be prevented easily by known means which are generally within reach.

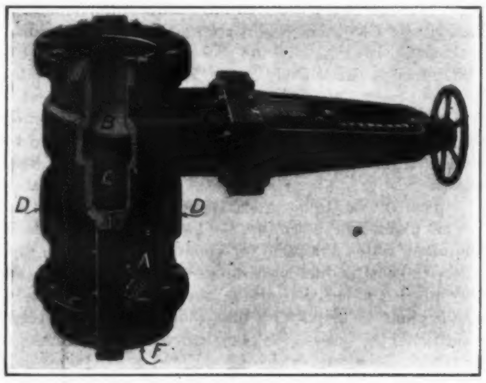
One of the most successful apparatus devised with a view to controlling whatever flow of oil or gas is encountered is the blow-out preventer which has given general satisfaction, particularly in drilling by the rotary method.

THE BLOW-OUT PREVENTER.

The blow-out preventer is a modified type of a stuffing-box casing head, which in turn is an addition to the four-way T. The immediate object of the preventer is to control the flow of oil or gas between two strings of casing, and naturally its use is better adapted to drilling by the rotary method in which the circulating water keeps an open space between the inner casing and the wall of the hole. An idea of its operation may be gained by imagining a four-way T attached to the top of the last casing set or landed and the inner casing passing through the T, the flow of oil or gas between the casings being deflected to the lateral openings of the T by closing the annular space between the inner casing and the upper part of the T by means of a stuffing box. The preventer, when used, is always placed on the last string of casing set or landed, thus controlling the flow between that string and the drill pipe or casing that is being lowered.

PRECAUTIONS AGAINST FIRES.

Perhaps the greatest individual losses in connection with flowing oil and gas wells have been caused by conflagrations which, in most instances, could have been avoided by proper precautions. In such conflagrations the gas, owing to its lower flash point, is generally set on fire before the oil. Ignition may be caused by fires under boilers or in forges, by unprotected lamps, burning matches, or spontaneous combustion at the bearings of the calf wheel, bull wheel, headache post or band wheel in the engine house. It is also claimed that the friction of pebbles striking each other or rubbing against the casing as they are expelled with great force with the gas or oil may cause sparks that will set on fire the more inflammable hydrocarbons. In certain oil fields, fires caused by lightning are comparatively numerous.



The Mortenson well capper.

The prevention of these fires depends on the proper control of the flow of gas and oil, the ventilation of the space immediately above and near the well so that no gas will accumulate, and the keeping of boiler fires, forges, lamps, burning matches, poorly insulated electric wires, etc., at such a distance or in such a position as to eliminate danger.

The most effective means employed for subduing gas or oil fires has been the use of steam discharged in great quantities and under high pressure against the lowest part of the flame, in a manner to be described in a later publication by the Bureau. Well cappers, such as the Mortenson, have also been used successfully. Nature at times comes to the rescue by temporarily stopping the flow when the well "sands up." On the other hand, the flow may render human ingenuity powerless by destroying the casing and forming a veritable oil volcano, as was the case in Mexico with the famous Dos Bocas well.

THE MORTENSON WELL CAPPER.

The Mortenson well capper, devised by A. C. Mortenson, and shown in the accompanying illustration, has been used successfully in the Midway and Coalinga fields for controlling oil wells of large flow after they have "gone wild." It is a modification of the straightway gate valve, differing from the latter principally in the design of the hub or barrel, which is made in two separate segments fastened together with bolts *A*. The gate *B* is nearer the upper flange, thus diverting the orifice into two chambers of unequal lengths, the larger one *C* having two circular openings *D*, 4½ to 6¼ inches in diameter. The recess *E* is designed to allow the gate to be drawn back of the clear about three quarters of an inch, thus making possible the clamping of the capper around the well casing without danger of damaging the gate. The lower part of the apparatus has a grooved shoulder *F* provided with hydraulic packing in order to prevent the back flow of oil or gas between the casing and the capper, there being enough space between the shoulder and the side openings to allow for the standard casing collar.

When the top connections have been made, the gate of the capper is opened slowly to allow some of the oil to flow through the capper and test the upper connections, and if these are found safe the gate is entirely opened. The gate valves attached to the side connections can then be closed without trouble, thus placing the well under perfect control.

This method has been found effective in controlling oil wells on fire, since, if it is possible to reach the casing one or two joints below the mouth of the well, the flow of oil can be diverted through the side openings and allowed to discharge at any safe distance away from the well.

In order that the sand usually accompanying the oil in the California fields may not wear out the metal cap, an oil cushion is provided. This consists of a pipe about 8 feet long, having a tight hardwood plug and a cast-iron screw cap on the opposite end. This chamber is constantly full of eddying oil and sand, and thus affords a yielding cushion that effectively retards the velocity of the sand grains and minimizes their wearing action. The wooden plug affords added safety, as it is not as quickly attacked by the sand as an unprotected metal cap. To the other opening of the T are connected the necessary fittings to divert the flow into as many channels as needed, and additional oil cushions may be provided if added safety is required.

Work of the Vienna Radium Institute*

Five papers from the Radium Institute at Vienna, by Drs. von Hevesey and Paneth, contain notable advances in our knowledge of the chemistry of the radio-active elements. The chemical identity of the several members of a group of isotopic elements has been further put to the proof and extended to include the electro-chemical properties. An elegant application of this new phenomenon of isotopy has been made in analytical chemistry in the determination of the solubility of such excessively insoluble compounds as lead chromate, sulphide, etc. The principle of the method is to add to the common element its radio-isotope in unweighable, but intensely radio-active, amount, and to estimate the distribution of the former after any chemical operation from the experimental distribution of the latter by radioactive measurements. Thus radium D, derived from the decay of radium emanation, is added to lead before its precipitation by potassium chromate. Radium D being isotopic with lead, the ratio of the lead and radium D must remain unchanged by the precipitation. The quantity of lead in the filtrate is, of course, analytically undetectable, but the quantity of radium D is easily estimated. In this way the solubility of lead chromate was found to be 0.012 milligramme per liter

Another important direction, in which these investigators are extending, is in the application of colloido-chemistry to the radio-elements. Often, as they and Godlewski in France have independently concluded, even these extremely attenuated solutions of the radio-elements behave as colloids rather than as electrolytes and their transport under the electric current is due to electrophoresis rather than to electrolysis. Polonium is the center of interest in many of these researches, for it is a new element, in the sense that it is isotopic with no previously known one, and occupies a separate place in Mendeléeff's table, so that its properties cannot, like those of the majority, be exactly determined by proxy.

Other papers deal with chemical decomposition produced by radium rays and ultra-violet light (Kailan), the solubility of radium emanation and other gases in liquids (Stefan Meyer and Martin Kofler), the variation in the ranges of the individual α particles through the probability variations in the number of molecules they encounter in their path (Freidmann), and the life periods of uranium and radium (Stefan Meyer). The last research treats critically the known data from which these constants can be derived, and leads to the result that there is complete agreement among values obtained by independent methods. The most probable values for the periods of average life of radium and uranium respectively are 2,500 and 7.23×10^9 years. Incidentally, it may be pointed out, this makes the perennial problem of the origin of actinium more of a mystery than ever, for there should be no such agreement among the methods, if, as is supposed, some 8 per cent of the uranium atoms branched off into actinium at some point before radium is arrived at. But it may still be doubted whether some of the data chosen, particularly the equilibrium ratio between radium and uranium, are not at fault.

* Mitteilungen aus dem Institut für Radium-forschung, xxxviii-lii. Ueber Neuerungen und Erfahrungen an den Radium-messungen nach der γ-Strahlenmethode. By V. F. Hess (*Verh. D. Physikal. Ges.*, 1913, xv., Nr. 20). Reviewed in *Nature*.

Selecting a Prime Mover*

Reciprocating Engine, Turbine, and Gas Motor Compared

By H. E. Longwell

IF one is designing a power plant, he must not become so obsessed with the question of mere steam economy that he will spend a dollar to save ten cents worth of steam, or ten cents to save some steam that costs nothing at all.

It is not unusual to find intelligent people who see the power problem with such a distorted perspective, that the single item of the steam consumption of the prime mover hides everything else. I recall two cases that were especially typical: one a wagon works in the West and the other a textile mill in New England. Both were using single-valve high-speed steam engines of a type that I regard with respect and affection, but which has been frequently and slanderously characterized as a "steam eater."

WHEN STEAM SAVING IS NOT ECONOMY.

The manager of the wagon works admitted that he was getting reliable operation from his engine with a minimum expense for upkeep. However, someone told him that Corliss engines would do the work with 25 per cent less steam, and he was appalled by the ruinous waste. Now this work includes some acres of dry kilns which require more steam than the total exhaust of the engine; in fact, it was practically impossible to detect any measurable difference between the fuel consumption on Sunday, when the engine was not running, and any regular working day. The fuel was all refuse from the wood-working machines and there was always a surplus which had to be burned in a destructor. By patient reasoning with the manager, he was able to see that if saving all of the steam used by the engine did not effect any noticeable reduction in the total fuel consumption, it would be hopeless to expect any economic benefits to accrue from a saving of 25 per cent of it; and, finally, it dawned upon him that, even if he could save a measurable quantity of fuel by installing another engine, his only return for the increased investment would be the joy of burning up his savings in the refuse destructor.

The textile mill mentioned engaged a new superintendent, and he could see nothing ahead but bankruptcy, unless the wasteful high-speed engines were replaced by a compound condensing engine. In this mill sundry washing and drying operations used up all the exhaust of the engine and some live steam besides. Before committing any blunders, the new superintendent was deftly and skillfully assisted to an understanding of one fundamental principle of power plant economics, to wit: If all of the exhaust steam from an engine is required for some useful purpose, that engine is furnishing power with an efficiency of 100 per cent, and any expenditure with the object of bettering that efficiency is not likely to be a temptingly profitable investment.

I have put some emphasis on the policy of attaching too much importance to the question of mere fuel economy in a power plant, because I think I detect a little tendency in this direction in the presentation of the problem that has been submitted as a foundation for this discussion. Sundry estimates are submitted as representing the probable costs of steam and electrical energy exclusive of administration, taxes, depreciation, and electric charges.

CONSIDERATIONS NOT TO BE OVERLOOKED.

The items of interest, taxes, insurance and depreciation, or to speak more exactly, amortization, are too important to be ignored. These so-called fixed charges or investment costs are, in general, greater in amount than the total cost of labor, operating supplies and maintenance. They are especially significant in that they measure the cost of fuel economy.

WHY THE GAS ENGINE IS NOT ATTRACTIVE IN THE ELECTROLYTIC REFINING PLANT.

To illustrate, let us consider the probable comparative performances of a high-grade steam-turbine plant and a gas engine, and producer plant consisting of several 1,500-kilowatt generating units. The electrolytic refining industry offers any investment in the interest of economy an unusually favorable opportunity to "make good," because it is permitted to work 8,760 hours per annum.

Assuming the fuel to be the highest grade of bituminous or semi-bituminous coal, having a calorific value of 14,500 B.t.u. per pound, the gas engine and producer plant would, under test conditions, effect the saving of one half pound of coal per kilowatt-hour over the turbine plant or say, two tons per annum. If the coal costs as much as $3 per ton, this would mean a saving of $6 per kilowatt-year.

The gas engine and producer plant will cost about $50 per kilowatt more than the steam turbine plant, and the question arises as to whether it is worth while to invest $50 in plant to save $6 a year.

Naturally, there will be differences of opinion as to what would constitute an attractive return on this extra investment. I should want 6 per cent for interest, 1 per cent for taxes, 1 per cent for insurance, and 2 per cent for maintenance, having due regard to the appalling speed with which new things in engineering become old, I shouldn't feel comfortable unless I had a sinking fund of 8 per cent to provide for the safe return of my capital, for some of these items amount to 18 per cent. In my opinion, the gross return should be not less than 20 per cent per annum, so that this saving of $6 per kilowatt-year, would be too expensive if it required an extra investment of more than $30 per kilowatt in plant equipment.

In thus calling attention to the importance of investment for fixed charges as a factor in the cost of power, I am only touching superficially the doctrine, that has been ably and vigorously preached and assiduously practiced by Henry G. Stott.

The determination of the true cost of electrical energy is a large subject, and those interested in it will profit by reading a paper entitled "Standardization of Methods for Determining and Comparing Power Cost in Steam Plants," which was presented jointly by Mr. Stott and W. F. Gorsuch at the June, 1913, meeting of the American Institute of Electrical Engineers and which is published in the May, 1913, issue of the proceedings of that Society. This paper is particularly happy in its treatment of investment costs.

With respect to the type of power plant best suited for the electrolytic refining of copper, we may safely eliminate gas-engine equipment from serious consideration.

THE ADVANTAGES OF STEAM IN THIS PROBLEM.

The plant will naturally be located where there is abundant water available for condensing purposes, and where the cost of fuel is reasonable. In other words, we may choose a location where the conditions enable a steam plant to display its best economy. Under these conditions, the gas-engine plant would be a doubtful investment, even were there no especial reason why it is not desirable for this particular class of work.

There appears to be one reason why the proposition is peculiarly one for a steam plant.

According to Mr. Addick's statement of the problem, if live steam were used for heating the electrolyte, the total steam from the boilers would be used as follows:

One half for electric-power generation, one fourth for steam-driven auxiliaries, and one fourth for heating the electrolyte. Steam-driven auxiliaries are not, as a rule, so efficient that they abstract any serious amount of heat from the steam passing through them so that for heating the electrolyte the exhaust from these auxiliaries would be practically as effective as an equal quantity of boiler steam. Therefore, the boiler steam required for auxiliaries and for heating the electrolyte would be approximately 50 per cent of the amount required for generating the electric current.

I am informed that in a plant having an output of 500 tons of refined copper per day, the waste-heat boilers connected to the reverberatory furnaces forming a part of such a plant, should be capable of supplying 50,000 pounds of steam per hour. This is somewhat over 40 per cent of the steam required by the main generating unit, or practically enough to operate all of the auxiliaries that would usually be run by independent steam motors in a steam-driven plant, and the exhaust from these auxiliaries would take care of the heating of the electrolyte.

This quantity of steam is too important to ignore, and even though gas-engine-driven main generating units were installed, it would be necessary to make use of this steam from the waste-heat boilers. The practical difficulty arises from the fact that while the tanks are operated continuously, it is not usual to run the furnaces on Sunday, consequently it would be necessary to have a considerable boiler plant in reserve to be operated only one day in each week to tide the plant over Sunday, and so, even if there were no question as to the commercial economy of a gas engine and producer plant, as a general proposition, this one practical operating condition would be sufficient to rob it of all of its theoretical advantages.

In a steam plant, the regular boiler equipment is so flexible that it will readily take care of the fluctuation in the output of the waste-heat boilers. Since with modern mechanical stokers it is not unusual to force boilers to 200 and 300 per cent of their normal rating, it is evident that no decidedly disproportionate boiler equipment would be required to carry the plant over the weekly interval in which the waste-heat boilers are out of commission.

THE ENGINE-TURBINE COMBINATION.

The combination of a compound-reciprocating engine exhausting into a low-pressure condensing turbine, looks, on first consideration, to be inviting, since it is generally admitted that, between the limits of the usual boiler pressure and atmospheric exhaust pressure, a reciprocating engine is usually more efficient than it is customary to make the portion of a complete expansion turbine that takes care of this part of the pressure range. While the superior fuel economy of this combination seems apparent from purely theoretical consideration, there is comparatively little available information regarding its amount in actual figures.

It is not denied that this combination has its legitimate uses, but it is most certain that mature judgment is required for determining the conditions under which it may be recommended, and it is equally certain that the combination has been installed in a number of instances in which its use was decidedly ill-advised.

Admitting the hypothetical economy of the combination, let us consider the features that tend to offset this advantage.

We have, first, increased the initial cost. A low-pressure turbine will, in many instances, cost 75 to 80 per cent more per kilowatt than a complete expansion turbine. That this is reasonable may be seen readily by an inspection of a sectional view through a typical expansion steam turbine of the Parsons type. Let us assume that the capacity of this machine is 3,000 kilowatts. What must we do to break this 3,000-kilowatt turbine into a low-pressure turbine of half this capacity? We simply cut out a small portion, and increase the inlet opening some six or eight times. But it does not require any unusual qualification to enable one to see that the part eliminated does not, by any means, represent one half of the cost of the 3,000-kilowatt machine. Neither would anyone expect to purchase 1,500 kilowatt capacity in a reciprocating engine for the cost of the section that has been eliminated from the complete expansion turbine. Again, no one would claim that the expense of installing the combination unit would be less than twice that of installing the single complete expansion unit. And no one would be hardy enough to suggest that the charges for attendance, maintenance, and operating supplies would be approximately equal for the two units.

There are doubtless cases in which the possibility of conserving reciprocating engines already in use would justify this combination type of unit, but in a plant that is new throughout, its desirability is, to say the least, highly problematical.

As far as actual authoritative figures, giving the comparative power cost for the two types of units, are concerned, Mr. Stott could give us these if he would. The most important installation of combination units in the world was carried out under his direction. He had the justification of conserving valuable reciprocating engine equipment, which was in excellent physical condition, and there can be no question but that the best possible engineering judgment was exercised in designing and executing the project. I am confident that Mr. Stott has accurate and comprehensive costs of electrical energy as generated by this plant, and that these costs represent the utmost possibilities of this type of unit.

If Mr. Stott would be willing to say whether or not, in an absolutely new plant, he would seriously contemplate the installation of combination reciprocating engines and low-pressure turbine units, such a pronouncement would be more convincing than many volumes of argument based purely on theoretical grounds.

WHEREIN THE TURBINE ALONE HAS THE ADVANTAGE.

As regards the comparative merits of compound and triple-expansion reciprocating engines and turbines as prime movers, the trend of general practice in power-plant design shows conclusively that the turbine has the advantage. It has economic possibilities at least equal to those of the reciprocating engine, and markedly better when working with the high vacuum obtainable with the newer types of condensing apparatus and the copious supply of cooling water that is invariably found in places that would be regarded as favorable for electrolytic copper refining plants.

I speak of the economic possibilities of a certain type of prime mover rather than of its inherent economy, because the latter is inseparably associated with the type. A prime mover is not economical simply because it is a

*From a paper entitled "The Power Problem in the Electrolytic Deposition of Metals," presented at a joint meeting of the New York members of the American Society of Mechanical Engineers, the American Institute of Electrical Engineers and the American Electrochemical Society, January 9th, 1914. Abstract published in *Power*.

compound engine, a triple-expansion engine or a turbine, but because it is economical by design. There are hundreds of triple-expansion engines that are less economical than some compound engines. In fact, I am not sure that there are authentic records of triple-expansion engines which show sufficient improvement over the economic results of the best examples of two-cylinder compound engines to justify the added complication and expense of the third cylinder and its connection.

It is possible to design a turbine that will be less economical than a very ordinary multiple-expansion reciprocating engine. On the other hand, turbines are built that under suitable operating conditions give economical results that cannot be equaled by the reciprocating engines of any type, however skillfully designed, if operated under the same conditions.

The advocates of the turbine can afford to be unnecessarily modest and claim no more than equality with other types of prime movers as regards steam economy, for there remain still the unquestioned advantages of the lesser cost and the smaller installation expenses.

THE GEARED-TURBINE DIRECT-CURRENT UNIT.

For some years, the turbine was at a disadvantage in plants in which it was desirable to generate direct current, for the reason that the rotative speed of an efficient steam turbine and the rotative speed of a reliable, efficient direct-current generator are not compatible. This disability has happily been removed by the development of a reliable transmission gear which allows any reasonable speed ratio between the turbine and the generator. This gearing has an efficiency of over 98 per cent and has been in public use long enough to demonstrate that, in point of reliability and durability, it is at least on a par with any other kind of apparatus forming a part of an electric-power plant.

While the geared direct-current unit costs more than an alternating-current turbo-generator unit of the same capacity, it is cheaper and somewhat more efficient than the combination of an alternating current unit and a rotary converter.

I am not in possession of reliable costs for compound reciprocating engine-driven units, but commercial experience indicates that the geared turbine-driven unit has an advantage as regards price f.o.b. at the factory. With space and installation costs added, the advantage is obviously more marked.

Figures purporting to give probable plant and unit-power costs are as a rule unsatisfactory because they are affected by too many variable factors. As regards plant costs, it might be said that, depending on the expensiveness, or simplicity, of one's architectural taste, his luck in selecting a contractor, his resourcefulness as a designer, his finesse as a buyer, the accessibility of the site selected, the state of the weather, and a lot of other things, he ought to be able to build a really good turbine-driven plant of from 6,000 to 9,000 kilowatt capacity for $75 per kilowatt, more or less.

As regards the cost of power, if one is satisfied with investment charges of 10½ per cent per annum; if he can buy really good coal at not to exceed $3 per ton; if he is a capable manager and a careful operator, and reasonably economical, he ought, with a plant of this size, to be able to produce a kilowatt-hour at the switchboard with substantially 100 per cent load factor for 4.3 mills, also subject to the qualification "more or less."

West Coast Trade Expectations at Panama

By Willis Fletcher Johnson

THERE is probably no more marked and general expectation concerning the Panama Canal than that its opening will lead to a great increase of commerce on the West Coast of South America and especially of trade between those countries and the United States. Men speak of the prospective "opening" of the West Coast to the world's commerce much as though that region had hitherto been in the condition of one of the old-time "hermit nations" of Asia. For this there is some superficial justification on the map. By any unbroken sea route that coast is remote from the chief centers of trade, and the opening of the canal will make it much more accessible. The shortening of the unbroken water route thither will be enormous. Between New York and Valparaiso the reduction will be from 8,460 to 4,637 miles; and between New York and Callao, from 9,603 to 3,392 miles. Between European and West Coast ports there will also be a marked lessening of distances. There can be no doubt that these changes will have a decided effect upon intercourse. They will greatly facilitate and expedite it. But the extent to which the actual volume of trade will be increased, and to which the United States will share in that increase, will depend upon some other circumstances as well as mere distance.

There is first to be considered the commercial capacity of the West Coast countries, which may be done in one pertinent respect by comparing their present volume of trade with that of others, in South America and elsewhere. In doing this we may omit Colombia, since it fronts upon both the Pacific and the Caribbean; and also Bolivia, because of its non-maritime situation. The comparison, so far as South America is concerned, will then be between Chili, Ecuador and Peru on the one side and Argentina, Brazil and Venezuela on the other. A table will show at a glance the chief elements of comparison, to wit: Population, total amount of foreign trade per capita, and percentages of imports from and exports to the United States.

	Population.	Commerce per cap.	Imports from U. S., per cent.	Exports to U. S., per cent.
Chili.......	3,415,000	$73.58	12.4	15.8
Ecuador....	1,500,000	14.45	28.1	29.9
Peru........	4,610,000	14.66	19.6	28.2
Argentina...	7,172,000	93.04	14.3	7.5
Brazil......	21,115,000	27.55	11.2	35.6
Venezuela...	2,744,000	16.81	30.6	32.5

The three West Coast countries, it will be observed, have less population and on the whole less commerce per capita than the others. Chili, however, has much more commerce than Brazil or Venezuela, and is not unworthy to rank even with the phenomenal Argentina. Indeed, the per capita trade of Chili is about two thirds as large again as that of the United States, and is larger than that of France or Germany. On the basis of comparison, then, we can scarcely expect it greatly to increase; while if we take into consideration Chili's peculiar geographical situation and character, the character and prospects of the bulk of its trade, and the density of its population, which exceeds that of most other South American lands, the probability of much further increase seems still more slight.

Ecuador and Peru have almost exactly the same per capita commerce, which is about half of Brazil's and somewhat less than Venezuela's. Ecuador's population is nearly twice a dense as that of Peru, exceeding even that of Chili, while that of Peru is almost exactly the same as that of Argentina, Brazil and Venezuela. We may reasonably atrribute Brazil's superiority in trade to the world-wide demand for her two chief staples, and the less superiority of Venezuela to her proximity to great markets. The trade of Ecuador and Peru does not, therefore, compare unfavorably with theirs. It is as large as that of Servia, and larger than that of Bulgaria or even of Japan. Moreover, which is perhaps more to the point, it is much larger than that of any Central American State save Costa Rica and Panama, and it is nearly as large as that of Mexico, which is only $15.84. Why, then, should it be expected to increase by leaps and bounds at the opening of the canal? If Mexico, fronting upon the two seas and abutting directly upon the United States and the Central American States, has not developed a larger trade, why should Ecuador and Peru be expected to do so?

It seems to me, then, that these West Coast States have already a volume of commerce not greatly out of proportion to that of other countries, and that its very great increase as a result of the opening of the Panama Canal is not reasonably to be expected. If the per capita trade of Peru were to be made as large as that of Venezuela, the gross increase would be only about $10,575,000; our share of which would be scarcely perceptible in our annual report. If Ecuador and Peru were both to attain as large a trade as Chili, it is true, there would be the very considerable increase of $360,000,000. But I can see no basis for such expectations.

There remains to be considered the question whether the United States is likely, by virtue of the canal or otherwise, to get a larger share of the West Coast trade than it now enjoys. At the present time we are getting a minority, and not even a plurality in any of the three. In Chili we stand third in both imports and exports, Great Britain being first and Germany second. In Ecuador we do a little better, but we stand second to Great Britain in imports and to France in exports. In Peru, the country which we have regarded as our best friend in South America, we stand second to Great Britain in imports, and third to Great Britain and Chili, in exports. But then our proportion of the trade of these West Coast states is as large as that with the other three named. In not a single South American country have we a majority of commerce.

Will the opening of the canal alone make any change in these conditions? I cannot see why it should. Brazil is readily accessible, yet we have a smaller proportion of her trade than of Peru's despite the latter's handicap. We have a larger share of Chili's trade than of Argentina's, and nearly as much of Ecuador's as of Venezuela's. Why should the opening of the canal make any material change? It will not abolish nor lessen the competition of the European powers. It will make the distance of the West Coast markets less, by the all-water route, for us, but also for our rivals. We must remember that we now enjoy, and have all along enjoyed, greater proximity to those markets than the Europeans who outstrip us in them. If with our original and permanent advantage we have not been able to take first place, what reason is there to expect that we shall do so merely through an increase in facilities which will be shared by our rivals as well as by ourselves? We might perhaps do so if we could close the canal against their traffic; but even the most radical misinterpreter of the Hay-Pauncefote treaty would scarcely venture to propose that.

Let me not be understood, however, as arguing that the canal will be of no value to us in our West Coast trade, or that we are doomed to hopeless inferiority in Latin American commerce. I have no thought of such a counsel of despair. The canal will be of service to us, though it alone will not give us commercial supremacy; and we can gain commercial supremacy, but not merely by means of the canal. The real question to be considered is not so much what effect the opening of the canal, *per se*, will have upon our West Coast or indeed any other South American trade, as whether, concurrently with that great improvement in facilities for all the world, we are going to adopt the improved methods of trade through which our rivals have overcome our natural advantages and have outstripped us in our neighbors' markets.

The first of these should be to adapt our offerings to our customers, instead of purblindly striving to make themselves adapt their tastes and desires to our wares. It has long been proverbial that while American and European commercial travelers in South America both carry sample bags, the former go thither with them full and the latter with them empty. The American carries samples of the goods which he tries to persuade his customers they ought to want. The European collects in his bag samples of the things which his customers are using and which they want, and takes them home to serve as models for the manufacturers who supply the export trade. The American tries to persuade the people, a peculiarly proud and sensitive people, that he knows better than they do what they want, and that they ought to want and to take the things which he supplies, no matter how outlandish they may seem to them. The European finds out what they want and supplies it, no matter how outlandish it may seem to him. The result is natural and inevitable. The European gets the orders. What does it matter if people want shoes without soles or pens without points? In the name of Hermes, let them have them! That is, if we are merchants and not pseudo-pedagogues.

The next need is that in selling goods we shall grant to our South American customers the terms of credit which they require, and which our European rivals unhesitatingly give. No South American pays cash. The demand for time is universal. The German or British house grants it as a matter of course, and the American house must do the same if it is to compete successfully. That will involve the establishment of American banking houses in those countries, and that is something which should be done for the sake of our reputation as well as for the facilitation of trade. The absence of American banks has often been remarked upon in much the same way as the absence of our flag in the ports. "The Yankees have no ships," they say, "for they have to send their goods in the vessels of other nations." Similarly, "The Yankees have no money," they say, "for they have no banks and they cannot afford to wait the usual time for payment of their bills."

Finally, it is necessary that after we have sold them our goods we shall pack them and ship them in a way suited to the climate and the conditions of transportation. There is really a difference, though some seem not to think so, between a cool, dry climate, and a hot and humid one; and that difference materially affects some goods and calls for a corresponding difference in the wrapping and packing. There is also a difference, strange as it may seem to some, between carrying goods in a freight car from New York to Chicago and carrying them on mule-back over the Andes. It has been disheartening, though sometimes irresistibly scorn-provoking, to stand on a South American dock and see goods from the United States unloaded, packed in as many different ways as Kipling says there is of writing tribal lays, with every blessed one of them wrong.

These are the chief practical measures which are needed, if we are to share in whatever increase of trade on the West Coast the opening of the canal is to bring, and if we are to gain for ourselves that larger proportion of the present and general commerce of South America to which our proximity and our political relationship seem to entitle us. To look to the mere opening of the canal as a sort of magic talisman, which will at the touch place us foremost in Latin American markets, would mean disillusionment, disappointment, and the reproach that we had built the canal for the commerce of other lands. If our expectations are to be realized, we must ourselves apply the means of realization.

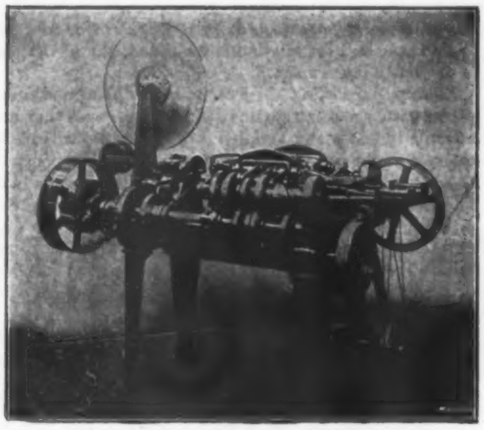


Fig. 1.—Machine which prints tickets and makes and attaches the pin for affixing to merchandise.

Fig. 2.—A battery of sixteen hair-pin machines on the assembling floor in the factory where built.

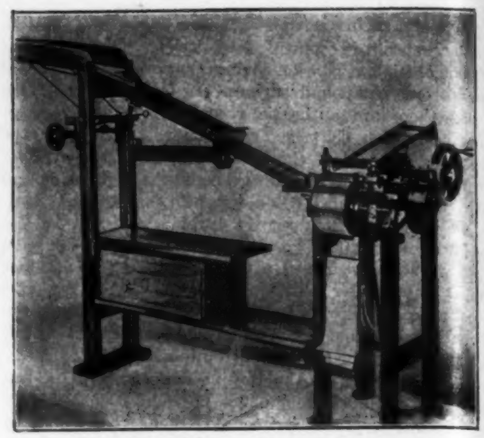


Fig. 3.—Pin-sticking machine which counts the pins and sticks them into papers.

Inventing Machines to Make Inventions Marketable*

Some Interesting Facts About Inventions and a Few Points That the Inventor Usually Overlooks

By E. R. Miner

PROBABLY ninety-eight out of every hundred men have, at times, dreams of becoming great inventors. Such dreams are usually colored by visions of some epoch-making discovery which will bring both fame and fortune. As a matter of fact, and according to history, the epoch-making discoveries have made comparatively few fortunes for the inventors. The fortunes have come to others after a long period of improvement, elimination, and practical trial. Where there is one Alexander Graham Bell or Thomas Alva Edison, there are a thousand unknown and unremembered inventors. Inventors, as the old saying has it, may be born, but successful inventions are matters of pure business, the gradual evolution of new dresses for old ideas, the working out of new methods, new goods, and new applications to meet recognized trade requirements.

Whereas the large fortunes which have been made by some great and timely discovery or invention can be counted on the fingers, the moderate fortunes which have been made by inventing some small article of practical and everyday use are not only numerous, but are well represented in all sections of the country. To merely invent something is not nearly as hard as knowing what to invent. Nearly any mechanic, if turned loose in a shop, could manage to invent things, but it would only be the occasional and exceptional man who would invent things which had a money value. The really new things or the radical changes are often the ideas of persons who have but a surface knowledge o' the business to which their invention applies. Not being bound by custom or by recognized methods or previous experience, they draw upon their imagination or inventive faculty. Lack of practical knowledge often does give that twist to the imagination which results in the new idea, but usually there must be a long period of experiment and the bringing into play of practical knowledge to make the idea successful.

An electric lineman might be employed for twenty years in stringing heavy electric cable, yet his duties seem so common-place that he never suspects or thinks that a large business could be created in making the clips or hooks which fasten the heavy cable to the supporting wire. The stranger, or possibly the young engineer who has charge of the line gang, being more or less unfamiliar with the work, notices the great number of clips or supports used. He also notices that the lineman cuts off a section of wire for making these clips, and immediately the idea is born as to why these pieces could not be manufactured more cheaply, more uniformly, or better, by machinery.

To successfully follow out such an idea, it is important to understand trade conditions, to know what the possible market would be, what price they would have to be sold at, what saving in labor or cost such article would represent, and after designing a clip which would meet all requirements, to know that a machine could be made for manufacturing such a clip both rapidly and cheaply. The failures in the invention business have been mostly by reason of the inventor going ahead on some idea which appealed to him personally, but on which his actual information was very small.

So apparently insignificant a product as the hairpin illustrates, in a simple manner, the development of an idea into an industry. Wild thorns, sharpened sticks and shaped pieces of bone or shell were the original hairpins. Later on, the goldsmiths turned out by hand various devices in the way of bands and pins for holding the hair. The inventor of the wire hairpin is unknown, but the original hairpin was probably a piece of wire bent over in the center to form two straight legs of equal length.

The practical man stepped in, and understanding the various deficiencies of the hairpin, as it existed, began to make improvements until to-day there are dozens of patents covering the point on the pin, the crimping or waving of the wires, the general shape, and other features which presumably make the hairpin better for the purpose intended. From this development, there proceeded the development of machines for manufacturing them. A hairpin made by hand, or one requiring considerable manual labor, would be a hairpin of rather high cost. As a consequence, the sales would be restricted. With automatic machinery, the hairpin becomes an article where cost is reduced to a mere trifle over the cost of the raw material, and as a consequence, it becomes an article of everyday necessity. A modern hairpin machine, depending upon the size and kind of the pin, will turn out from 75 to 200 per minute. At least one modern hairpin manufacturing company making nothing but hairpins keeps 75 machines running continuously, with a general average of 100 per minute or 6,000 per hour for each machine.

The improvements, the attachments, and the small changes that make a thing practical, make it conform to the requirements of the trade, and generally whip it into shape, are made by those who are thoroughly familiar with the business in hand, and know what will be required by trade usage. There are very few inventions that ever have or ever can immediately revolutionize conditions, trade, methods, or things in general. A design or invention that is different beyond a certain point is held up to ridicule as a freak, and regardless of actual merit, it may be years before the public will accept such a design or invention at its true worth.

Wise manufacturers seldom put out freaks, but rather keep to their general design, making small changes here, and others there, until the trade is led to accept a freak as an outgrowth of gradual improvement. Few inventors see the reasonableness or business policy in this. The true inventor would immediately revolutionize business. He forgets the interests of those who have money tied up in a competing article, and would stuff his invention into the hands of every member of the trade. Admitting that an invention had real and superior merit, this, without previous education, is not a selling point. One shotgun might be so superior to another shotgun that there would be no comparison, and yet there would be no argument that would influence the man whose knowledge of shotgun requirements could not grasp the technical difference. To him, they would both be shotguns.

To the general public, inventions that are radically new are things to let the other fellow fool with. This characteristic of the public will account for about one half of the failures of inventors to put a really meritorious article on the market. The inventor, therefore, to be successful in a financial way, should be a business man. He should be broad in mind, and willing to see things as they exist, and not as he would have them. He must recognize that all things must be manufactured,

*Reproduced from *Machinery*.

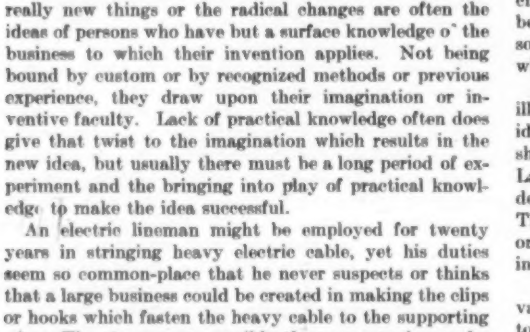


Fig. 4.—Top view of the principal part of the pin-sticking machine shown in Fig. 3.

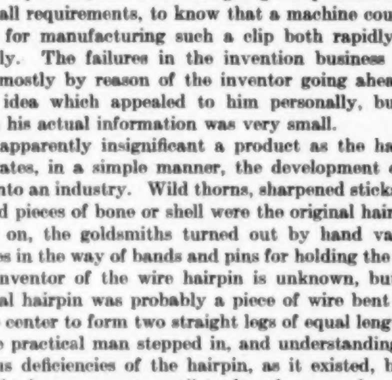


Fig. 5.—Automatic press performing six operations and provided with automatic stop.

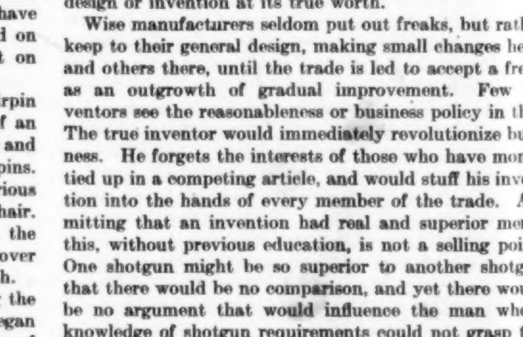


Fig. 6.—A machine which makes hinges for pianos faster than one could count them.

Fig. 7.—A spring winding machine which receives wire from the coil and completes springs at the rate of 150 per minute.

and to be of any pecuniary benefit, they must be sold. To be sold, a product must adhere more or less to certain well-defined standards. Such standards can be gradually altered, but they cannot be rushed at and immediately overthrown. In addition, to be manufactured at a cost which will admit of selling at a price which will be acceptable to the public and yet admit of a profit, special machinery or special applications of standard machinery may be necessary.

Successful invention (and by successful invention we mean invention which brings financial return to the inventor) is a business which requires close study of trade conditions and the possible demand brought about by modern improvement. The man who invents a garter clasp or a new type of hairpin, and can get them on the market in a proper manner, stands a better chance of being adequately rewarded than he who struggles for many years in an effort to build some type of a great power turbine.

There have been fortunes made on pins and other fortunes on hooks and eyes, but such fortunes have been built through a universal demand that called for quantity, and the popularity of these goods and immense sales for them have been created by reason of their very small retail cost. This low cost is made possible by automatic machinery that takes the wire or metal from a reel, feeds it through the machine, and drops out the completed article. Without such machinery, neither the pin business nor the hook and eye business would be possible, and the general public would still be using the makeshifts of our ancestors.

The inventor of the hook and eye, or the inventor of the pin, probably could not design a machine for making them, and they must perforce go to other inventors who could build one for them. Like thousands of other things, the hook and eye was an idea. Properly made and properly put on the market, it was a builder of fortune, but it required the machinery back of the hook and eye to make such an idea successful.

The machine part of the proposition is really the fundamental basis for success. Fish-hooks would still be made by hand and at home by those who use them, were it not for the automatic machines which turn them out so rapidly and at so low a cost that it would be a foolish waste of time and energy for anyone to attempt competition by older methods, even for their own use. The dollar watch is made possible through the design of special machinery. Even the automobile might still be an idea were it not for the machine builders who have made the rapid and uniform manufacture of the various parts possible.

Whether the article be a suspender buckle or a gas engine, the very first essential of operation will be "How can it be manufactured?" Financial success may entirely depend upon the answer to this one question. Throughout the New England States, that "Yankee district of the country so well known for its ingenious contrivances," there are shops which could be well called "inventor's factories." Probably the oldest of these, and perhaps the largest, is located in Bridgeport. To go through this factory is a liberal education on the reduction of cost in manufacturing methods. The founder was the inventor of the original pin sticking machine, which counts the pins and sticks them in papers, so many pins to the row, and so many rows to the paper. A comparatively simple contrivance, it revolutionized the pin business, and is used in every country where pins are manufactured. It was the machine in this case that put into the hands of the manufacturers a popular, easily handled package for the retail sale, while at the same time making a reduction of cost in handling.

There is practically no industry to-day where the machines for making some part of the product are not the real factors of success. We hear of the inventor of a typewriter or of some other product, but we never hear of or give a thought to the inventor of special machines and special attachments which make the manufacture of the typewriter or product possible. And in the same way, there are manufacturers of special machinery whose factories are probably unknown to the general business man, yet special machines of their design are in every corner of the world, and turning out completed products or parts for pretty nearly every line of business.

A recent visit to one of these factories showed on the testing floor, having a final try-out before shipment, the following machinery: An upholstery tack machine, a form of press which pulled wire off a reel on one side, flat metal from a coil on the other side, and delivered large round headed upholstery tacks at the rate of 125 per minute; a patent thumb-tack machine biting pieces out of a coil of flat brass and dropping those aids to the drawing board at 135 per minute; a butt hinge machine rolling off hinges faster than one would want to stand and count them; an electric lamp socket machine assembling the brass and porcelain sections at the rate of 60 per minute; a hook and eye machine spinning wire off a coil and dropping the familiar hump hook at 225 per minute; a paper clip machine making 300 clips per minute; a hairpin machine; a machine for making screw-on jar tops; a machine for making the wire guards for lanterns; a machine for making wire clothespins; a machine for making bed springs; a machine for making small springs; an

Fig. 8.—Paper clip machine which turns out finished clips at the rate of 450 per minute.

eyelet machine for glove fasteners; a safety pin machine; a pin ticket machine for clothing; a machine for making, printing, and coating with paraffine the paper caps for milk bottles; a capping machine for beer bottles; a bucket machine; a garter clasp machine; and a great variety of wire and metal bending and forming machines.

Often a single machine will be found adequate to supply a whole industry. At the speed of 100 per minute, there is a total of 50,000 to 60,000 pieces to represent a ten-hour day. Now, 60,000 pieces per day for 300 days in the year often represents a greater quantity than can be disposed of, and there are cases where one machine pays good dividends, and is run perhaps only half or quarter of the time.

Work which is done by hand represents labor charges. It, also, if fairly large quantities are wanted, represents lack of uniformity and interchangeability. High labor charges require a high selling price, and the higher the price, the more restricted the field. Bring machinery into the question, and the labor charges for a single piece drop, the selling price drops with it, the selling field is enlarged, and the greater quantity demanded increases the business and produces a larger net profit. The machine or manufacturing part of a proposition is often lost sight of by reason of the ingenuity shown in a device, or its evident salability. Wrecked hopes are the reward of such short sightedness. The world may be waiting for a device to accomplish a certain purpose, but it will continue to wait if the price is beyond certain set limits.

There are hundreds of men earning a most excellent income by devising practical improvements for everyday products. These men do not always know all the angles regarding the particular product they may be working on, but they waste but little time on developing an idea until they know the probable market price, the quantity likely to be sold, and that it can be manufactured for the price by machinery.

Comparative Strengths of Naval Powers*

The usual method of comparing the strengths of fighting efficiency of the various naval powers, by simply comparing the number of capital ships, only gives a very slight representation of the actual comparative strengths of two navies. If, for example, a certain navy had two super-dreadnoughts each mounting twelve 12-inch guns, whereas another navy possessed two super-dreadnoughts each mounting eight 12-inch guns, by the usual method of comparison these navies would be considered of equal strength, but if reckoned by gun power, the former has twenty-four 12-inch guns as compared with the latter's sixteen 12-inch, the former, therefore, having an extra fighting efficiency of eight 12-inch guns, which may be considered of almost equal strength to two battleships of the pre-dreadnought type. It is, therefore, obvious that the method giving the fairest comparison is that by which the main armament is the first consideration, the number and size of the vessels being a secondary consideration. The following table, compiled from the standard works of reference, shows a comparison between the British and German navies, these being considered the premier naval powers of the world. Only battleships constructed within the last twenty years may be considered as still efficient fighting units.

From the following table, it will be seen that Great Britain has nearly 100 per cent more vessels, and the total main armament of these is 580 guns against 319 on the German ships, showing a superiority of numbers of 81.8 per cent.

Shipbuilding and Shipping Record.

GREAT BRITAIN.

Type or Class.	Number of Capital Ships.	Main Armament. 13.5 in.	12 in.	9.2 in.
Battleships—				
Majestic	9	...	36	...
Canopus	6	...	24	...
Formidable	8	...	32	...
Duncan	5	...	20	...
Swiftsure	2	...	...	8 (10-in.)
King Edward VII	8	...	32	32
Dreadnought	1	...	10	...
Lord Nelson	2	...	8	20
Bellerophon	3	...	30	...
St. Vincent	3	...	30	...
Neptune	1	...	10	...
Colossus	2	...	20	...
Orion	4	40	...	...
King George V	4	40	...	...
Iron Duke	4	40	...	...
Battle cruisers—				
Invincible	3	...	24	...
Indefatigable	1	...	8	...
Australia / New Zealand	2	...	16	...
Lion	2	16	...	...
Queen Mary	1	8	...	...
Tiger	1	8	...	...
Armored cruisers—				
Cressy	6	...	...	12
Drake	4	4	...	8
Black Prince / Warrior	6	...	...	36
Shannon	3	...	...	12
	91	152	300	128

GERMANY.

Type or Class.	Number of Capital Ships.	Main Armament. 14 in.	12–11 in.	9.4 in.
Battleships—				
Hagen	3	...	...	9
Kaiser Fredrich	5	...	...	20 (9.2 in.)
Wittlesbach	5	...	...	20
Braunschweig	5	...	20	...
Deutschland	5	...	20	...
Nassau	4	...	48	...
Ostfriesland	4	...	48	...
Kaiser	5	...	50	...
Ersatz Weissenburg	4	40	...	...
Battle cruisers—				
Van der Tann	1	...	8	...
Moltke	2	...	20	...
Seydlitz	1	...	10	...
Armored cruisers—				
Furst Bismarck	1	...	...	4
Prinz Heinrich	1	...	...	2
	46	40	224	55

SUMMARY.

Power.	Number of Capital Ships.	Main Armament. 14 or 13.5 in.	12 or 11 in.	9.4 or 9.2 in.
Great Britain	91	152	300	128
Germany	46	40	224	55
Per cent more	97.8	280	33.9	132.7

Note.—Tables include all battleships, battle cruisers and armored cruisers.

The Marconi Wireless Suit

The History of Wireless Telegraphy as the Patent Lawyer Sees It

On March 17th last the United States District Court for the Eastern District of New York, the Honorable Van Vechten Veeder presiding, delivered an opinion in the infringement suit brought by the Marconi Wireless Telegraph Company of America, against the National Electric Signalling Company. The patents, which, it was alleged had been infringed, are those issued to Guglielmo Marconi on June 4th, 1901, and to Sir Oliver J. Lodge on August 16th, 1898, and acquired by the Marconi Wireless Telegraph Company.

In arriving at a conclusion the court found it necessary to examine the entire history of the signalling through space without wires, so that its opinion necessarily is an exhaustive treatise on radio-communication. It is impossible in the brief space at our disposal to publish the decision in full, for it covers no less than 96 printed pages. In the following paragraphs we present an abstract of the more important sections.

The patents involved in the suit relate to wireless telegraphy through the propagation, control, and detection of ether waves, commonly called Hertzian waves. Briefly, they disclose ways of organizing and operating electrical apparatus so as to constitute sending and receiving telegraph stations, whereby electro-magnetic waves, effected by the production of an electric spark between charged conductors and capable of traveling long distances before becoming dissipated, may be radiated in definitely related trains, corresponding to an intelligible code of signals and thereby detected at a distant station. The invisible electric waves running at tremendous speed over the surface of the globe, produce definitely detectable electric currents in conductors that obstruct their path. By timing the impulses electrically emitted from the sending station to produce the dots and dashes or short and long intervals of the Morse alphabet, the succession of the correspondingly received electric currents set up in the receiving station by the impact of the outspreading waves become interpretable as dots and dashes so as to convey messages to the receiving operator.

It was in 1888 that Hertz carried on the epoch-making series of experiments which have made radio-telegraphy possible. He published his researches in Germany, but his papers were collected, translated, and republished in England in 1893. Hertz's apparatus was of the simplest construction. To generate electric waves he employed an oscillator or radiator composed of two horizontal metallic conductors in the shape of plates attached to small rods terminating in polished metal balls. These rods were connected to the secondary terminals of an induction coil, and the two balls brought into close proximity to form a small spark gap. The interruption of the current in the primary of the coil causes a discharge across the spark gap, producing the spark in the ether which results in the radiation of a wave. During the passage of this spark the air gap between the balls becomes highly conductive, but the potential difference between the charged plates immediately begins to equalize itself by a series of rapidly damped surges.

The most important contribution of Hertz was the discovery of simple means for detecting the presence of such radiations. This device consisted simply of a single turn of wire forming a ring provided with a minute spark gap between two metallic knobs. When this ring or loop was held near an active oscillator, electric impulses were set up which revealed themselves by minute sparks at the gap between the balls. This, the first wireless detector, is known as a resonator. By a series of experiments, Hertz proved that such waves possessed characteristics of light, and he determined their length by direct tests. But inasmuch as he never succeeded in producing waves which were detectable at more than a score of meters or so, it is not surprising that he did not realize that he had disclosed the elements of a system of wireless telegraphy.

Sir Oliver Lodge and Edouard Branly improved upon Hertz's simple resonator by devising the coherer detector. The coherer, as it was named by Lodge, is based upon the discovery that the enormous resistance offered to the passage of an electric current by powders and metal filings is greatly reduced under the influence of electric oscillation, which causes the filings to cohere and become a conductor. In 1890 Branly described a variety of substances which he had found to be sensitive enough to detect Hertzian waves. Lodge employed a device consisting of a glass tube in the ends of which were sealed terminal wires connected to metallic electrodes, between which were placed a small quantity of iron filings. Upon subjecting this tube to an electric current, he caused the deflection of a galvanometer. Inasmuch, however, as the filings when once they have been made to cohere continue to cohere until their contact is mechanically destroyed, it was necessary, in order to detect a succession of waves, that some mechanical appliance should be provided whereby the contact should be destroyed and the tube rendered non-conductive as soon as the galvanometer was moved.

While these disclosures of the properties of waves generated in the ether, after Hertzian methods, excited general interest among scientists, no suggestion had been made of any practical application. In 1892 Sir William Crookes published an article in the *Fortnightly Review* on "Some Possibilities of Electricity," which drew attention for the first time to the practical aspect of Hertz's discovery.

In the following year, 1893, Nikola Tesla delivered a lecture before the Franklin Institute in Philadelphia on the subject of high frequency and high potential currents. Tesla was not dealing with Hertz waves, but, after discussing and describing certain apparatus for high frequency illumination and power transmission, he said: "The idea of transmitting intelligence without wires is the natural outcome of the most recent results of electrical investigation. . . . I do firmly believe that it is practicable to disturb by means of powerful machines the electrostatic condition of the earth, and thus transmit intelligible signals and perhaps power."

In 1895 a Russian scientist, Prof. A. S. Popoff, repeated some of the experiments of Branly and Lodge and gave an account of some experiments of his own, relative to certain substances which he had noted were detectors of Hertzian waves. In this article, Popoff also described a laboratory experiment in which he notes that in one of his detectors, consisting of Branly tube containing filings, were connected to a lightning conductor at one end and to the ground at the other, in connection with an electric bell and battery, this apparatus would note the existence of a distant thunderstorm in the Ural Mountains. Popoff concludes his paper with the following:

> "In conclusion, I may express the hope that my apparatus, with further improvements of the same, may be adapted to the transmission of signals at a distance by the aid of quick electric vibrations, as soon as the source of such vibrations, possessing sufficient energy, will be found."

No one had described and demonstrated a system of wireless telegraph apparatus adapted for the transmission and reception of definite intelligible signals. This was the state of scientific knowledge and practice when in 1896 Marconi applied for his first patent.

This patent "for improvements in transmitting electrical impulses and signals and in apparatus therefor," was originally issued to Guglielmo Marconi on June 13th, 1897, and re-issued under date of June 4th, 1901. According to this invention, electrical signals, actions or manifestations are transmitted by means of oscillations of high frequency, such as have been called Hertz rays or Hertz oscillations. At the transmitting station is employed a Ruhmkorff coil or other source of high tension electricity, having in its primary circuit a Morse key or other signalling instrument, and at its poles appliances for producing the desired oscillations. At the receiving station there is a local battery circuit containing any ordinary receiving instrument and an appliance for closing the circuit, which is actuated by the oscillations from the transmitting station.

At the transmitting station there is a battery and an ordinary Morse key in circuit with the primary of a Ruhmkorff coil. The terminals of the secondary circuit of the coil are connected to two metallic balls fixed at the ends of tubes of insulating material, such as ebonite or vulcanite. Similar balls are fixed in the other ends of the tubes. These tubes fit tightly in a similar tube, having covers, through which pass rods connecting the balls to the conductors. One (or both) of the rods is connected to the ball by a ball and socket joint, which permits the adjustment of the balls in accordance with the quantity and electro-motive force of the electricity employed. Directions are given in the patent with the respect to the adjustment of the spark gap, and for insuring the regularity and power of the discharge of an ordinary Ruhmkorff coil with a trembler-brake on its primary by causing one of the contacts of the vibrating brake to revolve rapidly by connecting it to a small electric motor.

At the receiving station is a battery whose circuit includes an ordinary telegraphic instrument and a circuit closer. The appliance employed as a circuit closer is a glass tube containing metallic powders or grains of metal, each end of the column of powder being connected to a metallic plate of suitable length to cause the system to resonate electrically in unison with the electric oscillations transmitted. Two short pieces of thick silver wire fitting tightly within the tube are joined to pieces of platinum wire. The tube is closed and sealed to the platinum wire at both ends. Directions are then given with respect to the size of the tube, the preparation and mixture of the powder or filings, and the sealing and operation of the tube. It is stated that the tube may be replaced by other forms of imperfect electrical contacts, and that instead of the tuned plates, tubes or even wires may be employed.

It is pointed out that when no oscillations are sent from the transmitting station the tube does not conduct the current and the local battery circuit is broken; but when the powder or tube is influenced by the electrical oscillations from the transmitter, it conducts and closes the circuit. When once started, however, the powder in the tube continues to conduct even when the oscillations have ceased; but if it be shaken or tapped the circuit is broken. A tube well prepared will instantly interrupt the current passing through it at the slightest tap, provided it is inserted in a circuit in which there is little self-induction and small electro-motive force. The two plates communicate with the local circuit through two very small choke coils, thereby preventing the high frequency oscillation induced across the plates by the transmitter from dissipating itself by running along the local battery wires, which might weaken its effect on the sensitive tube. The local circuit in which the sensitive tube is inserted contains a sensitive relay. The tapping is done automatically by the current started by the tube employing a trembler on the circuit of the relay similar in construction to that of an electric bell, but having a shorter arm.

Marconi's relation to his predecessors appears to be the following:

The fundamental principles upon which radio-telegraphy depends were discovered and demonstrated by Hertz with his simple form of oscillator and resonator. His oscillator was measurably efficient, but his ring resonator was suitable only for laboratory demonstrations. Righi improved the oscillator and the timely discovery by Branly of the action of electric oscillations upon powders and metal filings disclosed a practical method of detecting ether waves. The filings tube or coherer, was developed by Lodge, who added means for restoring the receptivity of the tube after the coherence of the filings under the impact of the waves. Employing the Hertz oscillator with the improved Branly coherer, Lodge demonstrated the transmission of waves by the deflection of a galvanometer. Popoff supplanted the galvanometer by a relay and bell, and for meteorological observations he used as a receiver a vertical aerial wire grounded at one end to a water pipe. Signals had been detected at a distance of more than 100 yards. The possibilities of utilizing ether waves in the communication of intelligence had been foreseen. As early as 1892 Crookes had conceived the idea of transmitting messages in the Morse code by such means.

Now, in his first patent, Marconi used improved forms of the Hertz-Righi oscillator and the Branly-Lodge-Popoff coherer or detector. Of the three forms of structure described, the first is the well-known horizontal type used by Hertz; in the second the plates or conductors of the transmitting station are suspended on poles; in the third there are vertically suspended conductors with grounded connections in both transmitting and receiving stations.

In actual use, after some early experiments, the third form of structure with vertical conductors and grounded connections at both stations soon superseded the others, and the structure reached its final form upon the abandonment of the elevated plates and the adoption of a vertical wire, an alternative mentioned in the patent specification. And the practical application of the structure is brought about by inserting a Morse key in the center and the ordinary receiving instruments in a local battery circuit in the receiver.

In his practical application of Hertz's discovery to telegraphic communication, it is apparent from his specifications that Marconi himself, as well as other scientists, at the time he filed an application for a patent regarded his improvement in the coherer as his substantial contribution to the art. In its immediate application, and for the relatively short distance attained in early tests, such a conclusion was doubtless correct, but in the subsequent progress of the art the coherer has been abandoned. The grounded vertical aerial wire or antenna of the transmitting and receiving stations, is, however, a fundamental feature of the later art. The tentative way in which this feature is advanced is characteristic of the state of scientific knowledge of that time. The precise action of the grounded vertical aerial or conductor is not yet agreed upon. The court thought, however, that it is immaterial whether Marconi

did or did not understand its method of operation. He understood and described its function and he expressly claimed it. Accordingly, it was found that the evidence established Marconi's claim that he was "the first to discover and use any practical means for effective telegraphic transmission and intelligible reception of signals produced by artificially formed Hertz oscillations."

He did not make a pioneer invention in the sense that he discovered the principles of the art at the same time that he applied them to practical use, as did Morse in wire telegraphy and Bell with the telephone. His patent was a pioneer in point of time; but he did not discover the principles nor did he invent the primary appliances upon which the transmission of electromagnetic waves is based. Marconi accomplished his result, using well-known principles and by combining features which had been disclosed by others, but which he improved and co-ordinated by adding features of his own invention, which subsequent knowledge has shown to be of fundamental importance.

In the patent in suit it was not the received energy which produces the indication, but it is the battery circuit which is released and set in action. Marconi described his coherer as a circuit closing device, and his patent does not suggest any other way of operating except by a circuit closer and opener. The defendant does not use anything operating on a similar principle. It has a permanently closed circuit without any variability of contact whatever. The defendant could not possibly use a coherer, and Marconi could not possibly use a rectifier without entirely altering their principle of operation. The pendency of a companion suit is of itself proof that to change from an apparatus in which the spark gap and the coherer are in the antennæ to a system in which the spark gap and detector are in separate circuits, coupled by transformers to the antenna, is a radical change carrying defendant's device outside the contemplated system of the patent in suit. A function of the complainant's coherer is to close a local battery circuit so that it may operate a relay; the function of the defendant's detectors is to accumulate the energy in an already closed circuit and thereby move a quantitatively responsive indicator directly. This is accomplished by the complainant by the breaking down of a gap by means of the electrical impact of the waves upon the loose filings; the defendant accumulates an oscillating current in a separate closed circuit, rectifies this current from a state of oscillating pulses in opposite directions to a succession of pulses in the same direction, and by the current moves the indicator.

Giving the claim in issue the broadest construction to which it can possibly be enlarged, it seemed clear to the court that it was not infringed by the defendant. Therefore the court found that the claim, although valid, was not infringed.

Passing now to the Lodge patent, No. 609,154, dated August 18th, 1898, its object is "to enable an operator by means of what is now known as Hertzian wave telegraphy, to transmit messages across space to any one or more of a number of different individuals in various localities, each of whom is provided with a suitably arranged receiver, and to effect other ancilliary improvements described and claimed.

"The method of intercommunication consists, according to my invention, in utilizing certain processes and apparatus for the purpose of producing and detecting a sufficiently prolonged series of rapid electric oscillations and in so arranging them that the excitation of a particular frequency of oscillation at the sending station may cause a telegraphic instrument to respond at a distant station by reason of being associated through a relay or otherwise, with a subsidiary circuit, capable of electric oscillations of that same particular frequency or of some multiple or sub-multiple of that frequency. Another distant station will similarly be made to receive messages by exciting at the sending stations alternations of a different frequency, and so on, and thus individual messages can be transmitted to individual stations without disturbing the receiving appliances, which are tuned or timed or synchronized to a different frequency."

In carrying out the invention the patentee specifies that he uses

"a definite radiator consisting of a conductor or pair of conductors A and A¹ of large capacity arranged either as a Leyden jar or preferably spread out into space, one of them being the earth when desired. For the purpose of combining low resistance with great electro-static capacity, the preferred forms of charged surfaces or capacity areas are cones or triangles or other such diverging surfaces with the vertices adjoining and their larger areas spreading out into space; or a single insulated surface may be used in conjunction with the earth, in which case the earth constitutes the other oppositely charged surface. To these capacity areas are joined a pair of polished knobs, forming a spark gap.

"Between either capacity area and its knob, I place a synchronizing self-inductance, that is—a coil of wire or metallic ribbon A², preferably insulated with any solid or fluid insulator . . . or in air, of shape suitable to attain greatest inductance with a given amount of resistance—the object of this coil being to prolong the electric oscillations occurring in the radiator, so as to constitute it a radiator of definite frequency or pitch, and obtain a succession of tone waves emitted, and thereby to render syntony in a receiver possible because exactitude of response depends upon the fact that the total number of oscillations in a suitably arranged circuit is very great, so that a very feeble impulse is gradually strengthened by accumulated action until it causes a perceptible effect on the well-known principle of sympathetic resonance."

Lodge was the first to realize that if he could get a long train of waves he could afford to diminish the amplitude of the first few of them, the desired result being secured by cumulative effect. The principle disclosed by him was that although a radiator with several swings is less violent at its first impulse than a momentary emitter, the lessened emitting power of a radiator may be largely compensated by a correspondingly prolonged duration of vibrations on the part of the receiver or absorber, thus rendering the radiator susceptible of tuning to a special similarly tuned receiver. The tuned receiver then responds, not to the first impulse of the radiator, but to a succession of properly tuned impulses, so that after an accumulation of the first few swings, the electrostatic charges in the terminal plates become sufficient to overflow and spit off into the coherer, thereby effecting a stimulation and giving the signal. The resonator tuned to some different frequency of vibration would be unable to accumulate impulses and hence would not respond—unless, of course, it was so near the radiator that the very first swing stimulated it sufficiently to disturb the coherer, in which case again tuning is impossible.

The compromise by which effective syntony was thus made possible in wireless telegraphy was effected by the introduction coil between the capacity areas of both transmitter and receiver, whereby the natural frequency of the circuits was not only diminished, but their electrical inertia was also increased, and in this way the transmitting circuit was able to create, and the receiving circuit to accumulate, the effect of a series of waves as distinguished from a single wave of great amplitude.

The court held that the Lodge patent in issue was valid and that the subject matter was not disclosed by the prior art. "That the claims in issue read upon the defendant's structure admits of no doubt. Both its sending and receiving stations comprise an elevated conductor, acting as one capacity area, and the earth connection as the other, with variable inductance coil between them for purposes of syntony."

The court next considered Marconi patent No. 763,772, the stated object of which is "to increase the efficiency of the system and to provide new and simple means whereby oscillations or electric waves from a transmitting station may be localized when desired at any one selected receiving station or stations."

The system "includes at the transmitting station the combination, with an oscillation transformer of a kind suitable for the transformation of very rapidly alternating currents, of a persistent oscillator and a good radiator, one coil of said transformer being connected between the aerial wire or plate and the connection thereof to earth, while the coil of the transformer is connected in circuit with a condenser, a producer of Hertzian oscillations or electric waves shown in the form of a spark producer, and an induction coil constituting the persistent oscillator controlled by a signalling instrument." The system also "includes at the receiving station an oscillation transformer, one coil whereof is included between the aerial receiving wire and earth, constituting a good absorber of electrical oscillations, while a device responsive to electric waves, such as an imperfect contact or a device for operating the same, is included in a circuit with the other coil of said transformer."

The essential features of this apparatus and its departure from previous methods of operation are apparent. In his first patent Marconi had disclosed a method and apparatus for the effective transmission of wave energy through the ether of space and for its utilization in the communication of intelligible signals. In this early apparatus the energy was quickly radiated and as quickly absorbed. By reason of this characteristic his radiator could not create nor could his receiver store up the effect of a sustained train of waves necessary for the utilization of the principle of resonance. It was an effective apparatus for distress calls and purposes of that kind, but there was necessarily interference between messages. Moreover, the electric energy that he could get into his transmitter was necessarily limited. The energy supply had to be adapted to the elevated conductor. The capacity of a vertical wire is not great, and the extent to which it may be increased by lengthening the wire or adding capacity areas is obviously limited. Lodge came forward with a new idea. Although he recognized the impossibility of having a circuit which should be at once a good radiator or absorber and a persistent oscillator, he proposed a compromise. He increased the persistence of vibration of his radiating circuit at the expense of its radiating qualities, and increased the accumulative power of his receiving circuit at the expense of its absorbing qualities. Effecting this compromise by means of the introduction of an inductance coil in an open circuit, he obtained a train of waves of approximately equal amplitude and thus rendered effective syntony possible. But the syntony thus obtained was utilized for selectivity alone. It was obtained at the expense of the radiating and absorbing qualities of the circuit, and Lodge still supposed that for distant signalling the single pulse or whip crack was the best.

Marconi's improvement in his second patent upon his own prior apparatus, and his solution of the difficulty involved in Lodge's compromise, consists in the substitution for a single circuit in both transmitter and receiver of a pair of circuits, one of which is so constructed as to radiate or absorb readily, and the other to oscillate persistently and be a good conserver of energy. By using two linked circuits in his transmitter, in which the circuit of the primary contains a condenser of any desired capacity, with the usual provision for its discharge through the spark gap, and in the circuit of the secondary, the vertical wire, any required energy may be imparted to the radiator, since the closed circuit of the primary is a good conserver or reservoir of energy for the radiating open circuit of the secondary. This arrangement would be futile, however, without means whereby the stored energy of the reservoir circuit could be transmitted to the elevated conductor at the rate at which that conductor could effectively radiate it. The mode of getting the energy from the reservoir circuit into the radiating circuit, in like measure, as it is radiated, is the tuning of the persistently oscillating circuit to the radiating circuit. In this way the principle of resonance is fully utilized between the two circuits. Similarly, the two circuits of the receiver are linked through a transformer, so that electrical oscillations in an open and absorbing primary build up similar oscillations in a closed and conserving secondary until the coherer breaks down. Finally, the four circuits must be tuned together.

With this apparatus Marconi communicated across the Atlantic in 1901, and the claims in issue constituted the essential details of apparatus which has since made possible communication over a distance of 6,000 miles. It is used in more than 1,000 installations by Marconi and is admittedly an essential feature of the wireless art as at present known and practiced.

After examining the defendant's apparatus and considering the references cited by the defendant, the court held that this last Marconi patent was valid, not anticipated and infringed.

Material in Cast-Iron Flywheels and Pulleys

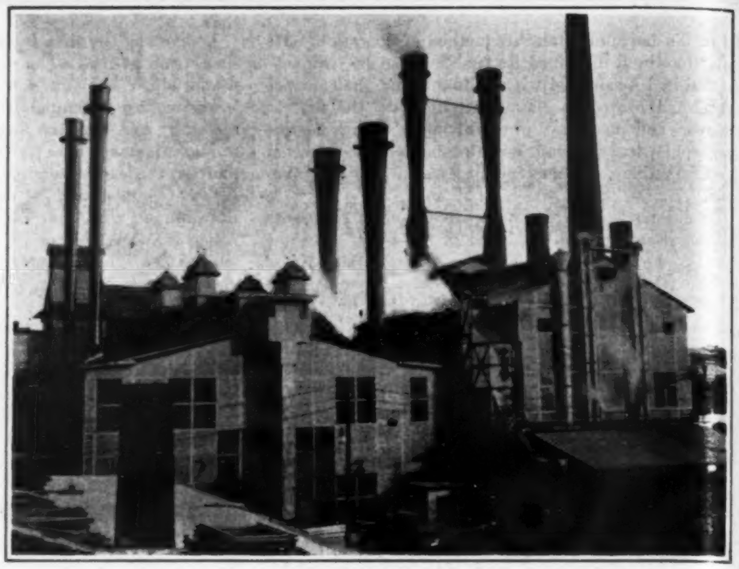
Wheels of this kind sometimes burst without any apparent cause, the load, speed, and running conditions being normal at the time of the accident. When the material is examined, it may be that no defects can be discovered on the fractured surfaces, and that no cracks, blow-holes, nor discolorations can be found. Furthermore, when the fractured parts of the wheel are tested for strength, there is often no physical evidence, whatsoever, of inferiority in the material.

An accident may sometimes result from internal stresses in the material, due to faulty design or to careless cooling of the casting; but severe internal stresses seldom occur except in wheels made in one piece. Some other explanation must therefore be sought for accidents of this nature, and the cause will often be found to be the use of improper raw material in the foundry. Chemical analysis frequently shows that the iron is not of a grade suitable for machine castings. This is particularly likely to be the case in wheels from small foundries that turn out all kinds of work, because in such places the same grade of raw material is likely to be used for castings of all kinds. A considerable part of the output of a foundry of this sort requires metal that will flow freely, so as to fill the forms well. (In making ornamental work, for example, it is highly important to obtain a sharp impression.) Such iron invariably contains a large percentage of phosphorus. Phosphorus lowers the melting point, but makes the iron brittle; and machine castings should never contain more than four tenths of one per cent of it. There is on record a case where a pulley burst under ordinary running conditions, and where no defects could be discovered in the broken wheel by a visual examination; but an analysis of the iron showed that it contained 1.37 per cent of phosphorus, or nearly 3½ times the maximum that should have been allowed. There is little doubt but that brittleness of the metal, due to this high percentage of phosphorus, was the cause of the break.

From a safety point of view, it is exceedingly important to make cast-iron wheels of material with a low percentage of phosphorus, and having a composition specially adapted to this class of work in other respects, also.—*The Travelers Standard.*

Wireless Weather Reports in Russia.—The Nicholas Central Physical Observatory at St. Petersburg (the headquarters of the Russian meteorological service) now sends a daily weather bulletin to the radiotelegraphic stations at Libau, Riga and Reval, for the use of mariners on the Baltic Sea who may apply for such information. A small charge is made for this service. Similar arrangements have been made with respect to the Caspian Sea, and the service will shortly be extended to the Black Sea, the Pacific, and the Arctic Ocean.

5,000 horse-power induced draft installation of the Centrale Electrique de Sweveghen, Belgium.



25,000 horse-power induced draft installation of the electricity station at Sampierdarena, Italy.

European Induced Draft Installations

Constancy and Ready Control the Advantages Over Natural Draft

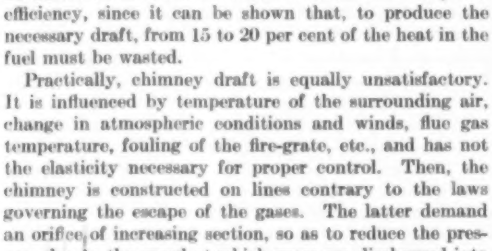
By Frank C. Perkins

The accompanying illustrations and drawings show the construction and method of operation of modern induced draft installation plants with fan, in or out of circuit, as designed by Engineer Louis Prat, of Paris, France.

Chimney draft is commonly referred to as natural draft. The chimney, as a draft producer, has numerous drawbacks without corresponding advantages. Technically, the method is primitive, as the draft is due to the difference in weight between the hot gases in the chimney and the surrounding air, and the chimney might be described as a hot air motor with an extremely low efficiency, since it can be shown that, to produce the necessary draft, from 15 to 20 per cent of the heat in the fuel must be wasted.

Practically, chimney draft is equally unsatisfactory. It is influenced by temperature of the surrounding air, change in atmospheric conditions and winds, flue gas temperature, fouling of the fire-grate, etc., and has not the elasticity necessary for proper control. Then, the chimney is constructed on lines contrary to the laws governing the escape of the gases. The latter demand an orifice of increasing section, so as to reduce the pressure due to the speed at which gases are discharged into the atmosphere and so augment the useful draft. Finally, the chimney, always cumbersome, demands costly foundations, especially if the soil should not be quite suitable, hence high capital cost.

The mechanical draft of Louis Prat with fan "out of circuit or in circuit" was designed to provide an exhausting apparatus of minimum resistance to the flow of gas by means of short and straight passages, with increasing cross section toward the outlet.



55,000 H. P. induced draft installation applied to chimney of power station, St. Denis, France.

It is intended to add, by a mechanical device and without creating a complementary resistance, sufficient pressure to augment the speed of the gas when necessary and if possible to vary automatically that acceleration according to the condition and thickness of the fire. This system, which is composed of a special tube forming a chimney, always indispensable in a boiler plant, in which a medium under pressure of external air, or a portion of the flue gases provided by a fan in close proximity, produces, by its escape, an artificial draft under the action of which the main gases are carried forward. This tube, called a pressure transformer on account of its property of changing into suction the pressure of the air or gas supplied, comprises the following essential parts: A base fitted at the lower part with an angle such that it can be bolted to the masonry. The chimney is self-supporting, thus guy ropes can be dispensed with. There is also the expansion chamber for air or gas injected, and a diverging tube forming a diffuser, having for its object a reduction to the minimum of the pressure necessary for the escape into the atmosphere of the motive air and the induced gases.

The base comprises a bent conduit containing the blower, and is connected to the fan discharge together with an auxiliary steam injector (as a stand-by) to maintain the draft in the event of temporary stoppage of the fan due to failure of power supply, etc. When necessary, the stand-by may work simultaneously with the fan. In the event of a temporary shut-down of one or more boilers, this might prove a boon, owing to the great augmentation of draft possible. The foregoing constitutes an arrangement particularly strong and simple, constructed of heavy work and without a weak or moving part. The result is great ease in operation and upkeep practically *nil*.

While the technical and practical advantages of this draft are owing to the extremely low resistance of the chimney, it has been repeatedly demonstrated in installations of this type that, on chimney draft alone, the same rate of combustion can be obtained with a much shorter chimney of this type than in the case of the ordinary one. Owing to the arrangement of the pressure transformer, which is in direct communication with the flue gases, the apparatus has to provide only a slight addition to the chimney draft, while its presence adds practically nothing to the resistance of the circuit which it terminates.

Further, it demands for its operation only 0.3 up to 1 per cent of the boiler power, the figures varying with the extent of the resistances of the plant on which it works. These results are not attainable with other systems of mechanical draft. In the direct suction method, the damper must be always fully closed, otherwise the fan will work in short circuit with bad effect. Owing to the changes in direction and the contractions and expansions encountered by the gas, the resistance of the circuit becomes an important factor, and, nine times out of ten, exceeds the value of the chimney draft which should be available.

In the case of forced draft it is necessary, in current practice, to provide for a fan discharge pressure of about 2½-inch water gage. This is equal to about ten times the resistance of the fuel bed. The low power required for this system is only one of the advantages to be derived from its use. As the fans employed work on considerably reduced orifices, one fifth or one sixth of a suction draft fan, the impellers may be of a smaller diameter without impairing the fan efficiency, the latter being from 60 to 75 per cent.

The position of the pressure transformer in relation to the steam-raising plant, its small dimensions and weight, demanding small space and unimportant foundations, allow it to be fixed directly on the main flue, economizer or even on the boiler, as was done in the case of the Thomson Houston Company at Lesquin les Lille.

At La Foudre Spinning Mill, Rouen, there is a plant with a chimney 49 feet high. The latter replaced an existing brick chimney 148 feet high, and with most economical results. With the same number of boilers, the same stokers, and the same quality of coal, the evaporation per pound of coal over a seven days trial was 8.164 pounds with this draft, and over a ten days trial with chimney draft, 7.385 pounds, an increase in efficiency of

$$\frac{(8.164 - 7.385)\ 100}{8.164} = 9.54 \text{ per cent.}$$

This draft is characterized by its large range, being capable of automatic variation up to three times its normal value, depending on the extent of the resistance in the generating plant. This is an important feature,

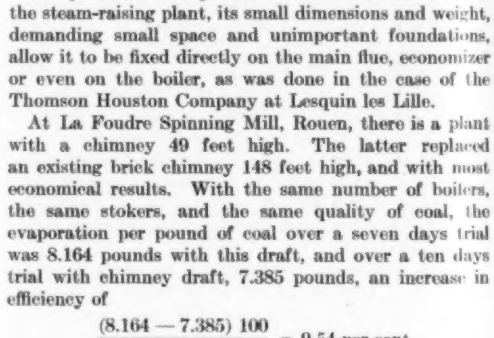
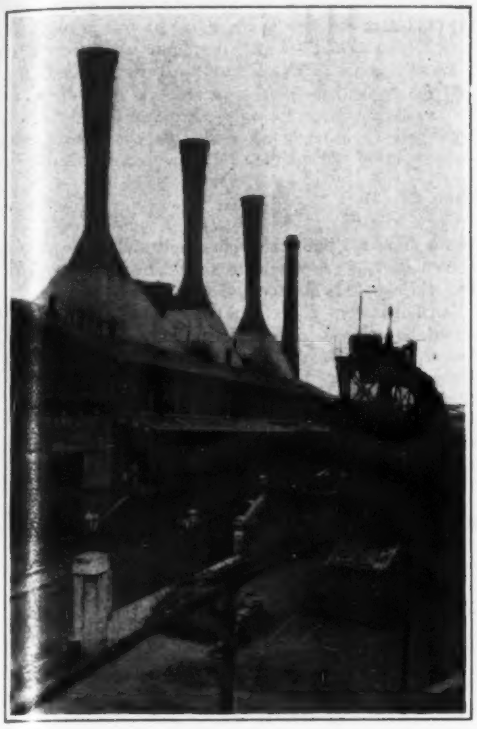


Diagram of induced draft system in circuit and out of circuit.



Induced draft system for 5,660 cubic feet per second for ventilation of the retort houses of the Bordeaux Gas Lighting Company.

because when the fires are newly charged the resistance to the passage of the air is increased, therefore the volume tends to diminish, and unless the draft is increased at the same moment the result is incomplete combustion and smoke production.

It is necessary then that the draft should vary according to the resistance of the fuel bed, and it is obvious that the ideal draft would be that of which the intensity would vary automatically, following the state of the fire. This result obtains with the pressure transformer where it is concerned with the constant work of aspiration.

Most remarkable results have been shown in comparative tests made on a boiler with a chimney 21 feet 6 inches high and this draft siphon, and with a chimney 65 feet 6 inches high and natural draft, with which the boiler was already fitted. These figures show that the same boiler and mechanical draft were able to produce almost double the amount of steam as when operated on natural draft, and, further, the mechanical draft resulted in about 14 per cent increase in efficiency. These results indicate that the fuel economy is due to the improved combustion by providing the coal with the correct quantity of oxygen to insure complete combustion, thereby increasing the furnace temperature, raising the CO_2 in the flue gases and avoiding the formation of CO.

The greatest economies are not entirely due to better utilization of the fuel, but to the use of cheap fuels such as slack, dross and screenings which have a lower market value than the fuels generally employed, although they may have equal calorific value. It is in this way that economies of 20 and 30 per cent, and even 50 per cent, have been realized.

At cement and lime kilns there are increased output and lower fuel consumption with this system. Generally, the vertical kilns work on simple natural draft and with low output.

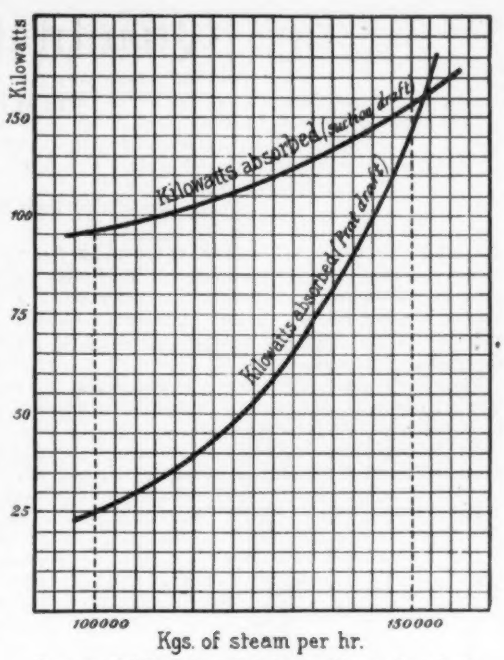
For pottery ovens there is improvement in burning and economy of fuel. Natural draft is usually met with in brick, tile and briquette works, where it is altogether unsuitable for the purpose intended. In effect, better utilization of the heat in the gas necessarily implies longer circulation in the kiln, but as this increases the resistance, and consequently reduces the natural draft, the output of the kiln is diminished.

It is in such particular cases that mechanical draft shows to best advantage. Its use permits the gases to be discharged into the atmosphere at from 40 to 50 deg. Cent. For melting furnaces there is increased temperature, reduced melting period and considerable increase in production, and for re-heating furnaces in iron and steel works there is great improvement.

This system may be applied to existing brick chimneys. In many cases, for example, existing installations, a brick chimney may be already at hand; in this event it is only necessary to accelerate the draft. The pressure transformer is well adapted for this purpose, its small size allowing it to be placed inside the brick chimney.

Thus the benefit of the natural draft due to the height of the chimney is retained, as the apparatus introduces only a slight resistance to that of the circuit, so slight that in practice it may be neglected. Consequently, the proper demand for the acceleration of the draft becomes extremely small.

An installation of this type serves boilers rated at 55,000 horse-power at the St. Denis Electricity Station, near Paris. Each brick chimney is 182 feet high and



Curves of kilowatts absorbed with suction draft and induced draft.

contains a pressure transformer dealing with the gases from six boilers, each having 4,540 square feet heating surface. Before the installation of the mechanical draft plant, the natural draft, varying with the weather conditions, fluctuated from 0.59 inch to 0.87 inch wg., and the evaporation varied between 16,500 and 17,600 pounds of water per hour per boiler. After the alterations, the evaporation reached 30,800 pounds per hour per boiler, and the draft 1.42 inches wg. at the chimney base.

It is of interest to consider the life of steel chimneys. Ample experience shows that such installations have extremely long lives, as they are still in service after nearly thirty years' work. Not only is the steel chimney preferable to that of brick, from the point of view of lower capital cost and light weight, requiring a small foundation, but air leakage is prevented, while a brick chimney, as a rule, contains many fine cracks, and, not being a conductor as steel is, there is much to fear from the effects of lightning.

Pyrometer for Superheater Locomotives*

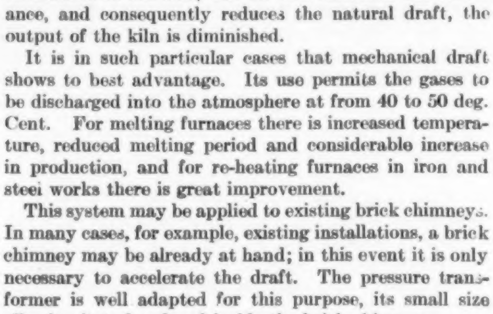
While it is true that remarkable economy results from the operation of locomotives equipped with superheaters, even when the best practices are not followed in handling them, the highest economy is obtained when the engines are given proper attention at the terminals and are carefully handled on the road. Whether the engines are receiving the care that they should at the roundhouses and are being efficiently operated on the road is best determined by the amount of superheat produced.

Recognizing the need of an indicator whereby the engineer could, at all times, be informed as to the temperature of the steam in the steam chest, attempts were made to find a suitable pyrometer for this purpose. Several instruments of both the pressure and electrical types were tested and found to be unsuited to the severe conditions under which they would have to operate. In order to get a satisfactory instrument for this purpose it was necessary to develop one that would meet the requirements established by the service in which it must operate. The conditions to be met were those of excessive vibration, varying temperatures and atmospheric conditions, as well as the rough handling to which devices on locomotives are subject. To meet these conditions required delicacy of adjustment and freedom of operation, combined with increased sizes of parts and durability of construction.

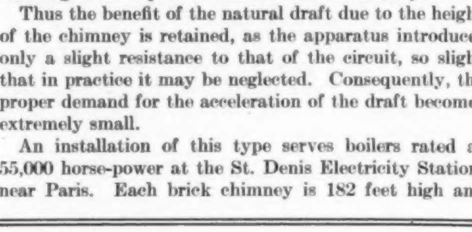
An instrument specially designed for use in connection with superheaters consists of thermo couples, constructed and arranged in accordance with the Bristol system. The cold end is located in the boiler, in the saturated steam, and the hot end in the steam chest, directly in the flow of the superheated steam. Electrical connections are established to an indicator of the milli-voltmeter type, located on the gage bracket in the cab.

The ends of the couples are so located that a variation of the outside temperatures has practically no effect upon them. The cold end of the couple, placed in the boiler in the saturated steam, is subject to only the slight variation in temperature due to the variation of the steam pressure, which does not vary more than a few pounds when the locomotive is in operation. The hot end of the couple, placed in the steam chest in the flow of superheated steam, is subjected to a range of temperatures from that of saturated steam to about 650 degrees. The difference in electromotive force generated by the hot and cold ends of the couples is read directly in degrees Fahrenheit on the dial in the cab.

The electrical lead and extension between the couples and the instrument are designed to provide flexibility



Arrangement of the parts of the pyrometer apparatus.



Section through the saturated steam fixture

and the least amount of deterioration resulting from handling and bending. They are insulated with a specially prepared composition, which is affected by neither moisture nor temperature, and they are finally enclosed within a flexible bronze armor which prevents them from being bruised by substances falling on them.

The instrument itself is of the milli-voltmeter, double jeweled Weston type, the movement having been very carefully designed from a standpoint of accuracy and lightness, in order that it may be depended upon to register accurately the extremely low electromotive force generated by the thermo couples. At the same time its construction is substantial enough to withstand the vibration and the temperature conditions to which it is subjected. The dial of the instrument is graduated to read directly in degrees Fahrenheit, and has a range of from 250 degrees to 750 degrees. The pointer and graduations are carefully selected with the purpose in view of making them distinctly visible at all times under the light conditions that prevail in a locomotive cab.

When a superheater locomotive is standing or drifting with the throttle closed, there is, of course, no superheat being obtained, and the indicating hand of the pyrometer instrument in the cab will be at the left hand side of the dial, reading between 350 and 390 degrees, assuming that the boiler pressure carried is 200 pounds or less. As the throttle is opened and the engine starts to work, steam from the boiler passes through the superheater pipes and the superheating process begins. As the engine starts, the pointer will move from left to right on the scale, showing an increased temperature in the steam chest, and as the engine is worked harder the superheat added to the steam increases until, under average conditions, the indicator registers between 600 and 650 degrees.

When the pyrometer operates in this manner, it is an indication to the engineman that the locomotive is being handled so that the maximum saving that the superheater makes available is being obtained. If it fails to operate in this manner, it shows him that either the locomotive is not being operated to produce the best results or that it has not received the proper attention at the roundhouse.

* The *Railway Age Gazette*.

Method of Preserving Bread.—Otto Bitter of Rochester, N. Y., has secured patent No. 1,089,945 for the method of preserving bread against staleness in which the bread is inclosed in a sheet of paper coated with wax or paraffin having a few small openings so distributed that air is admitted in such quantities that a molding action is prevented, while at the same time the action which produces staleness is retarded.

Quantitative Colorimetric Analysis—III*

Its Theory, Laboratory Methods and Apparatus

By G. A. Shook

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 1995, Page 208, March 28, 1914

WE have already considered some of the typical forms of colorimeters and spectrophotometers which may be used for the determination of the concentration of a colored solution, and we will now take up in detail the method of determining the constants necessary for the calculation of concentrations.

The theory of the colorimeter is so simple that it requires no special detailed study, but with the spectrophotometer the case is quite different.

As the essential points can best be brought out by concrete examples, we will consider at length some data

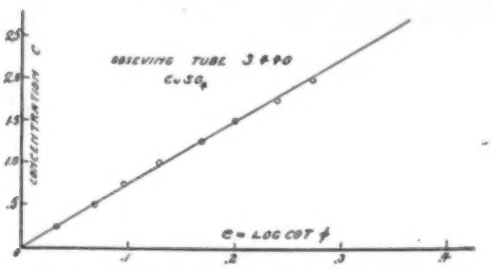


Fig. 1.—Calibration curve for copper sulphate.

obtained on simple solutions like copper sulphate and cobalt chloride by means of one of the more complicated instruments, for instance, the Koenig-Martens polarization spectrophotometer. Salts of these solutions may be quickly and easily made up, and they are, therefore, good material for practice work.

A thorough knowledge of a particular instrument, combined with a little manipulative skill in using it, is almost indispensable for the execution of a complicated problem in colorimetry, and such experience may be most easily obtained by beginning with the simplest cases.

The data used in this paper are obtained from observations made either by the writer or students of his laboratory, and may give some idea of the accuracy obtainable with limited experience.

CALIBRATION OF A KOENIG-MARTENS POLARIZA ION SPECTROPHOTOMETER.

There are three general methods which may be used to calibrate a spectrophotometer, and the choice of either must be determined by the conditions under which the instrument is to be used.

(1) When only a rough estimation of the concentration of a solution is required and when only a few samples of the particular substance are to be examined, then it is sufficient to make up a solution of known concentration and to determine the corresponding extinction coefficient for some definitely chosen color.

The absorption ratio may then be calculated, by means of which an unknown concentration may be readily determined.

Consider a special case: A 10 per cent solution of copper sulphate gave a reading on the Nicol scale of 43.2 degrees (43 deg. 12 min.), when the reading of the observing tube was 3.045. The color corresponding to this arbitrary number is green.

The extinction coefficient is, therefore,

$$\varepsilon = \log \cot \phi = \log \cot 43.2 = 0.027$$

and the absorption ratio is

$$A = \frac{c}{\varepsilon} = \frac{10}{0.027} = 370.$$

A 25 per cent solution gave a reading of 40.4 degrees, and its extinction coefficient is, therefore,

$$\varepsilon = \log \cot 40.4 = 0.070.$$

Hence the concentration by the optical method is

$$c = A\varepsilon = 370 \times 0.070 = 25.9 \text{ per cent.}$$

(2) If an accurate determination is required, then it is preferable to make up several solutions, varying in concentration over a range that will include all the concentrations of the unknown solutions.

Suppose, for example, that the samples to be tested range in concentration from 1 per cent to 5 per cent, then it is well to make up five solutions of 1, 2, 3, 4, 5 per cent concentration respectively, or, if they range from 10 per cent to 50 per cent, make up five solutions of 10, 20, 30, 40, 50 per cent concentration respectively.

The absorption ratio may then be determined for each of the five solutions and the mean may then be used for subsequent calculations.

The data of Table I were obtained from copper sulphate, the results being plotted in Fig. 1.

* Reproduced from *Metallurgical and Chemical Engineering*.

TABLE I.—OBSERVING TUBE 3.440 (RED) $CuSO_4$ (DILUTE).

Concentration in per cent	Rotation of Nicol ϕ	Extinction coefficient ε	Absorption ratio A
0.25	42.8	0.033	7.58
0.50	40.5	0.069	7.25
0.75	38.7	0.096	7.81
1.00	36.6	0.129	7.75
1.25	34.1	0.169	7.47
1.50	32.2	0.201	7.50
1.75	30.0	0.239	7.33
2.00	28.1	0.272	7.37
		Mean A,	7.51

Now, if we calculate, by means of the average value of A determined from the above data, the concentration of the solution made up to 2.00 per cent, we obtain

$$= A\varepsilon = 7.51 \times 0.272 = 2.02 \text{ per cent.}$$

This represents an average accuracy, and if we consider the 0.75 per cent solution, whose absorption ratio deviates farthest from the mean, we obtain the following value for its concentration:

$$c = 7.51 \times 0.096 = 0.72 \text{ per cent.}$$

In all of these numerical examples, the concentration of one of the standard solutions is calculated by means of the average value of A, merely to illustrate the method and to give a general idea of the accuracy obtainable.

Instead of taking the mean of the five values of A, for subsequent calculations, we may plot c against ε on cross-section paper. Such a curve is shown in Fig. 1. The data used in plotting this curve were obtained from Table I.

According to theory, this curve should be a straight line and should, moreover, pass through the origin of the axes, but, of course, all the points will not lie on a straight line, owing to unavoidable experimental errors. If the departure from a straight line is not greater than might be expected, we may assume that Beer's law holds for the particular substance, at least for the range of concentrations chosen.

As long as this linear relation obtains, we are not concerned, at least in practice, about the ultimate cause of the color; that is, whether it is due to the molecule, the positive ion or the negative ion.

When such a curve is once constructed, then for future work it is only necessary to set the observing tube to 3.440 and to obtain the reading of the Nicol for the particular solution in question. If the log cotangent of this angle is obtained from a table, then the concentration may be read directly from the calibration curve.

(3) A third method is to construct a table giving the concentration corresponding to every circular degree on the Nicol scale. In this way all calculation whatsoever is avoided, it being only necessary to determine experimentally the angle of rotation of the Nicol, such that a photometric balance is obtained for the particular solution.

This expedient is justifiable whenever a large number of samples are to be tested. The greater the accuracy required the greater must be the number of standard solutions made up. Portions of such a concentration table, which were constructed from the above data upon copper sulphate are given in Table II.

TABLE II.—OBSERVING TUBE 3.440 (RED).

$CuSO_4$		10 millimeter cell	
ϕ	c	ϕ	c
20	3.29	31	1.66
21	3.12	32	1.56
22	2.95	33	1.40
23	2.78	34	1.28
24	2.63	35	1.16
25	2.48	36	1.06
26	2.34	37	0.92
27	2.19	38	0.80
28	2.06	39	0.69
29	1.94	40	0.57
30	1.79		

This table was constructed as follows: Take, for instance, the first angle, 20 degrees, log cot 20 = 0.439, hence

$$c = A\varepsilon = 7.51 \times 0.439 = 3.29.$$

Now, if a copper sulphate solution of unknown concentration produces a reading of 30 degrees on the Nicol scale, its concentration is found directly from the table to be 1.79 per cent.

The best color, or wave-length of light, to use may be determined experimentally, if more than one standard solution is made up. If the solution is blue, then it will absorb more red light than blue light and consequently the red part of the spectrum should be used, provided that the sample is not too concentrated.

For if it is very dilute, the blue part of the spectrum cannot be utilized, since the rotation of the Nicol, ϕ, necessary to produce a balance, will be so small that an accurate value of the extinction coefficient cannot be obtained.

If it is very concentrated, too much light will be absorbed in the red, and consequently a good balance cannot be made.

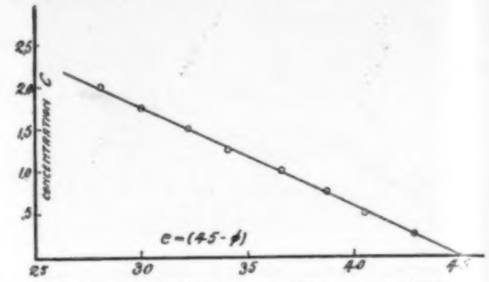


Fig. 2.—Calibration curve for copper sulphate (approximate method).

These effects are shown in a striking manner by means of the following data obtained from a blue salt, copper sulphate:

Weak Blue Solutions ($CuSO_4$).
Observing Tube 3.440 (Red).

CONCENTRATION IN PER CENT, c.				
0.25	0.50	0.75	1.00	1.25
ROTATION OF NICOL, ϕ.				
42.8	40.5	38.7	36.6	34.1

This gives a fairly wide variation of ϕ, so that accurate results may be obtained. For high concentrations, the absorption in the green was found sufficiently great, as is shown by the following data:

Strong Blue Solutions ($CuSO_4$)
Observing Tube 3.045 (Green).

c	10	15	25	30	45
ϕ	43.2	42.1	40.4	38.6	36.9

In like manner for weak, red solutions one cannot employ the red part of the spectrum, as is seen from the following results:

Weak Red Solutions ($CoCl_2$).
Observing Tube 3.540 (Red).

c	1	2	3	4	5
ϕ	43.6	42.6	42.1	41.5	40.7

The difference in the reading of the Nicol in this case is obviously not sufficient for accurate work.

The green part of the spectrum was then used for the same solutions with the following results:

Weak Red Solutions ($CoCl_2$).
Observing Tube 3.000 (Green).

c	1	2	3	4	5
ϕ	41.5	35.6	31.9	27.7	22.9

However, for strong solutions of cobalt chloride the red part of the spectrum is best adapted, as shown in the following table:

Strong Red Solutions ($CoCl_2$).
Observing Tube 3.540 (Red).

c	10	15	20	25	30
ϕ	37.4	35.7	32.9	30.6	27.9

To determine the best position of the observing tube, fill the cell with the weakest solution and obtain a rough balance in different parts of the spectrum, noting the reading of the observing tube for each position. Repeat the same operation with the strongest solution and then choose the position of the observing tube which gives the greatest change in the reading of the Nicol for the two solutions.

What has been said in regard to calibrating the Koenig-Martens instrument may be applied to any spectrophotometer. In the case of the double-slit instrument, one is concerned with the width of a slit and not with the rotation of an analyzing Nicol. Consequently the expression for c will be different.

For work where extreme accuracy is not required the polarizing instrument has this decided advantage over other types, namely, that the relation between the log cotangent of the angle made by the analyzer and the angle itself is approximately linear at least from 45 degrees down to 25 degrees. This simply means that instead of looking up the log cotangent of ϕ, each time, we may simply use ϕ.

To illustrate: the data obtained on copper sulphate, Table I, were used to plot a curve with c and ϕ as coordinates and it is seen from Fig. 2 that the points lie on a straight line which passes through 45 degrees, where the concentration is zero, as would be expected, for if the concentration is zero the fields are equally bright and therefore the Nicol must make an angle of 45 degrees. The extinction coefficient then assumes the simple form

$$e = 45 - \phi$$

whence

$$c = Ae = A\,(45 - \phi)$$

and

$$A = \frac{c}{45 - \phi}$$

The absorption ratios for the various concentrations are given in Table III.

TABLE III.

Concentration in Per Cent. c	Absorption Ratio. A
.25	0.114
.50	0.111
.75	0.119
1.00	0.119
1.25	0.115
1.50	0.117
1.75	0.117
2.00	0.119
	Mean A, 0.116

The 2 per cent solution gives a reading of 28.1 and, therefore, by this approximate method its concentration is

$$c = Ae = 0.116\,(45 - 28.1) = 1.96 \text{ per cent.}$$

An inspection of the two curves, Fig. 1 and Fig. 2, will show at once that for the particular data at hand the points obtained by plotting c and ϕ will not deviate from a straight line any more than the points obtained by plotting c and log cot ϕ.

Of course, it is not necessary to plot a curve if one calculates A for each concentration, for if the variation in the values of A is not greater than might be expected from experimental errors then the exact method need not be resorted to.

If the initial balance is not carefully made, then A will not be constant for different values of c, although a straight line may be obtained by plotting c and e. The straight line thus obtained, however, will not pass through the origin.

If it is found that A is not constant for a particular set of standard solutions, it is best to plot a curve before concluding that Beer's law does not hold, for the variation in A may be due only to an error in the "zero" reading.

A rule for determining roughly the best wave-length or color to be used when this particular instrument is employed may now be formulated.

Since the entire angular change of the Nicol should be about 20 degrees, the reading on the Nicol scale for any particular concentration may be calculated approximately. Let us suppose we have a range of concentrations extending from 1 to 5 per cent.

It has been shown that

$$c = Ae = A\,(45 - \phi)$$

and it follows that

$$c/e = c'/e' = c''/e'' \;.\;.\;.\; = \text{constant.}$$

Now, if $c = 1$ per cent and $c' = 5$ per cent, then since the reading of the Nicol for the 5 per cent solution should be about 25 degrees, the reading for the 1 per cent solution must be about 41 degrees for

$$c/c' = 1/5 = (45 - \phi)/(45 - 25)$$

or

$$\phi = 41 \text{ degrees.}$$

Hence, for the five concentrations, the corresponding readings on the Nicol scale must be approximately as follows:

CONCENTRATION IN PER CENT c.				
1	2	3	4	5
READING OF NICOL SCALE ϕ.				
41	37	33	29	25

The method of procedure would be as follows: Fill the cell with any of the five solutions, say the 3 per cent solution, and set the Nicol to 33 degrees. Now, rotate the observing tube until an approximate balance is effected and note the reading of the observing tube scale.

For example, five concentrations of potassium permanganate were made up as follows: 0.01, 0.02, 0.03, 0.04 and 0.05 per cent. In order to make an approximate balance for the 0.03 per cent solution, it was necessary to move the observing tube to 3.400 (red) when the Nicol was set at 33 degrees.

The following readings were then obtained for the five solutions:

CONCENTRATION c.				
0.01	0.02	0.03	0.04	0.05
READING OF NICOL SCALE ϕ.				
40°	35.8	32.5	28.5	25.1

This general method of determining the proper color may always be applied to the Koenig-Martens instrument whatever method is used to calibrate it. If one wishes only approximate results and makes up only one standard solution, then the best color may be readily found by the above method.

CONCENTRATION OF COLORLESS SOLUTIONS.

The concentration of a colorless solution may sometimes be determined by means of a spectrophotometer if a reagent can be added which will produce a color or which will cause the solution to become turbid.

For example, if a solution of barium chloride is added to a solution of potassium sulphate, a fine, white precipitate is formed by the insoluble barium sulphate. Since all the other salts in the solution are soluble and, moreover, colorless, the density of the precipitate, that is, the number of absorbing molecules per cubic centimeter of the absorbing medium is directly proportional to the concentration of the potassium sulphate provided an excess of the barium chloride is added.

As long as the precipitant is colorless and soluble, an excess of it merely plays the rôle of a solvent. By means of the spectrophotometer, we can get a measure of the absorption caused by the precipitate, and hence it is readily seen that such an instrument may be employed for this class of analysis.

When the percentage of potassium sulphate in any unknown solution is once determined, then it is only a matter of calculation to obtain the percent of SO_4, S, or O, etc.

In coal analysis, we are concerned with the amount of sulphur present, while in water analysis with the amount of SO_4. We might, of course, add an excess of the sulphate and then determine the percentage of chlorine in barium chloride, etc.

We will now consider a few examples. The average value of the absorption ratio, A, determined from three solutions of potassium sulphate was 0.0577. The solutions were made up to 0.02, 0.01 and 0.005 per cent of SO_4.

For the solution made up to 0.005 per cent, the extinction coefficient was found to be equal to 0.089 and, therefore, the optical method gives, for its concentration,

$$c = Ae = 0.0577 \times 0.089 = 0.00512 \text{ per cent.}$$

In the same manner, data were obtained for the determination of the percentage of chlorine in sodium chloride. A silver salt was used as a precipitant. In order to keep the precipitate in suspension long enough to make the necessary readings, rather dilute solutions had to be used. The following data were obtained:

Estimation of Cl in NaCl by means of the absorption of AgCl.

Concentrations based on the per cent of Cl.

c	0.0570	0.0429	0.0286	0.0143
ϕ	38.5	40.6	42.2	43.8

The average value of A from the above table is 0.651.

For the 0.0286 per cent solution, the optical method gives the following results:

$$e = \log \cot 42.2 = 0.043$$

and therefore

$$c = Ae = 0.651 \times 0.043 = 0.028 \text{ per cent Cl.}$$

We may consider one more example of a similar character, namely, the estimation of calcium in calcium chloride (Table IV). In this case, ammonium oxalate is added to the calcium chloride solution and the absorption of the insoluble calcium oxalate is taken as a measure of the concentration of the calcium.

This is a good example of the ability of such an instrument to detect the presence of very small quantities. The concentrations are based upon the per cent of calcium.

TABLE IV.—ESTIMATION OF Ca IN CaCl.

c	ϕ	e	A
0.00125	42.4	0.039	0.0320
0.00250	39.0	0.092	0.0272
0.00500	33.4	0.181	0.0362
0.01000	24.2	0.347	0.0289
			Mean A, 0.0311

The concentration of the 0.01 per cent solution is from the above value of A:

$$c = Ae = 0.0311 \times 0.347 = 0.0108.$$

The estimation of iodine in potassium iodide is a good example of the determination of the concentration of a colorless solution (Table V).

Iodide of potassium is colorless, and in order to develop a color, a reagent was added which would liberate the iodine and not produce an additional color. Dilute nitric acid was used in this case. We might use $K_2C_2O_7$ to liberate the iodine, but this reagent gives an additional color. Alcohol was also added to hold the liberated iodine in solution.

TABLE V.—ESTIMATION OF I IN KI.

Concentrations based on per cent of I.

Observing tube 3.000 (Green).

c	ϕ	e	A
0.25	20.5	0.427	0.586
0.125	31.4	0.214	0.585
0.0625	37.1	0.121	0.516
0.0313	39.7	0.081	0.387
0.0156	42.4	0.039	0.402

The data of Table VI, upon resublimed iodine dissolved in alcohol, are given to show the systematic variation of the absorption ratio A. This change in the value of A is probably due to the oxidation of the iodine into hydriodic acid which is colorless.

Beer's law evidently does not hold in this case, and accurate results could not be obtained except for a limited range of concentrations.

TABLE VI.—ESTIMATION OF IODINE IN ALCOHOL.

Observing Tube 3.000 (Green).

c	ϕ	A
0.25	18.8	0.535
0.125	29.5	0.507
0.0625	35.9	0.446
0.0313	39.4	0.367
0.0156	41.9	0.331

The absorption ratio A can almost always be determined by means of data obtained from controlled experiments. For instance, in order to determine the percentage of P_2O_5 in a sample of fertilizer it is not necessary to have a number of samples of fertilizer in order to determine A. This may be illustrated by an example.

The following method of preparing the solutions and the sample of fertilizer to be tested is due to Prof. Spitzer, of Purdue University, who has perhaps done more work in colorimetry than any other chemist in this country.

The solutions were prepared from a standard solution of calcium phosphate. The phosphate was first precipitated as ammonium phosphomylbdate. This insoluble precipitate was then washed with dilute nitric acid to free it from the soluble ammonium phosphomylbdate, and finally dissolved in a dilute solution of potassium hydroxide.

Hydrogen sulphide gas was then passed through this solution, causing it to turn to a clear, yellow color. The color depends upon the concentration, and it varies from yellow to brown. This solution was then diluted according to the percentage of P_2O_5 required. The data for six different concentrations of P_2O_5 are given in Table VII.

TABLE VII.—ESTIMATION OF P_2O_5 AS MOLYBDIC SULPHIDE.

c	ϕ	e	A
0.00078	44.1	0.014	0.0557
0.00156	42.0	0.046	0.0340
0.00312	40.1	0.070	0.0445
0.00623	35.6	0.145	0.0430
0.0125	28.8	0.260	0.0480
0.02500	17.5	0.502	0.0499
			Mean A, 0.0459

A sample of fertilizer secured from the agricultural experiment station was made strongly ammonical, and then a slight excess of nitric acid was added according to the directions of the official methods of analysis.

This solution was heated to about 80 deg. Cent. and an excess of ammonium molybdate solution was then added and the heat continued for an hour.

The precipitate, phosphomolybdate of ammonia, was then collected on a filter and well washed with dilute nitric acid to free it from any traces of molybdate solution.

It was next dissolved in a boiling solution of 5 per cent potassium hydroxide. Sulphurated hydrogen was then passed through this solution for twenty minutes, causing it to assume a deep red color due to the formation of the molybdate sulphide.

The solution gave a reading of 30 degrees on the Nicol scale, whence its extinction coefficient is

$$e = \log \cot 30 = 0.239$$

and its concentration is

$$c = Ae = 0.0459 \times 0.239 = 0.0110.$$

But 125 cubic centimeters of the original solution represents 1 gramme of fertilizer, hence the per cent of P_2O_5 in the fertilizer is

$$c = 125 \times 0.0110 = 1.37 \text{ per cent.}$$

The value obtained by the station was 1.51 per cent. Prof. Spitzer has carried out a number of such determinations and his average error is considerably less than this.

It is sometimes more convenient to use actual samples for making up standard solutions than to attempt to make, as it were, artificial standards. For instance, in the determination of the per cent of combined carbon in steel by colorimetric methods, one can obtain from the U. S. Bureau of Standards samples of steel which have been accurately analyzed by chemical methods. These samples range in carbon content from a few tenths of 1 per cent up to several per cent.

We will now consider at length a practical example. A 1 per cent solution of iron was made from a sample of malleable iron containing 3.40 per cent of combined carbon. This solution was then diluted so as to make four more solutions of different concentrations. Data were then obtained upon these five standard solutions by means of a Lummer-Brodhun spectrophotometer of the ordinary form.

The importance of an accurate initial balance is clearly brought out by the first set of data obtained upon these iron solutions.

Both slits were set at 30 and a cell containing water was placed in front of one slit. The lamps were then

adjusted until the two photometric fields appeared equally bright and without making any further check upon this balance both slits were opened to 100. The data given in Table VIII were then obtained.

TABLE VIII.—ESTIMATION OF CARBON IN IRON.

Concentrations based upon per cent of iron.

Observing tube 72.0 (Green).

c	R	e	A
0.125	58.9	0.229	0.546
0.250	51.0	0.292	0.857
0.500	43.0	0.365	1.37
0.750	33.6	0.474	1.58
1.000	27.0	0.567	1.77

R is the reading of the slit, and therefore,

$$e = 2 - \log R.$$

One might infer, at first sight, that Beer's law does not hold in this case, since A varies continuously.

If, however, c is plotted against e it is readily seen that a linear relation obtains, hence we may infer that the law does hold.

The cell, filled with water, was again placed in position and an accurate balance was obtained by adjusting the slit which was not covered by the cell. The average reading of the slit was found to deviate considerably from 100. as might be expected.

It was then set at 100 and the other slit (i. e., the one covered by the cell) was carefully adjusted until a balance was effected.

To make sure that the balance was accurate the first slit was again reset a number of times and the average reading was found to be 99.88. The other slit, which read 125.2, was left intact and the data of Table IX were obtained upon the same solutions.

TABLE IX.

c	R	e	A
0.125	88.9	0.051	2.45
0.250	76.4	0.117	2.14
0.500	62.9	0.201	2.49
0.750	50.0	0.301	2.49
1.000	38.0	0.420	2.38

It is seen from the above the variation in A is not more than might be expected from experimental errors.

The second solution, 0.25 per cent, was slightly turbid consequently its absorption ratio A is too low and it should, therefore, not be considered in determining the mean A.

The data of Table X, for the determination of the per cent of sulphur were also obtained by means of the same instrument. Barium sulphate was precipitated from a solution of potassium sulphate by adding an excess of barium chloride. Due to the rapid precipitation of the barium sulphate, only a few readings can be obtained before the solution becomes non-homogeneous.

If the cell is shaken and then allowed to stand a few seconds, the solution will again become homogeneous and the readings may be repeated. In this manner, it was possible to obtain fairly consistent results.

TABLE X.—ESTIMATION OF SULPHUR AS BARIUM SULPHATE.

Concentrations based upon per cent of sulphur.

Observing Tube 72.0 (Green).

c	R	e	A
0.005	69.9	0.155	0.0323
0.010	55.3	0.257	0.0389
0.015	32.5	0.488	0.0307
0.020	28.3	0.548	0.0366
		Mean A,	0.0346

It is thus seen, from these few examples, that any first-class spectrophotometer may be universally used for the determination of the concentration of a colored or turbid solution.

Laying Up Heating Boilers*

At this time of year the owners of heating boilers prepare to lay them up for the summer season. We are often asked how to do this, so that the boilers may be in the best possible condition for use in the fall; and we are therefore confident that the present article will be found timely and welcome.

Care should be taken, when discontinuing the use of a heating system, to see that all the radiators and pipes are thoroughly drained; and in order to make sure that this condition is realized, it is desirable to open the air-vents on the radiators in all cases, so that air may enter the system freely and prevent water from being entrapped in any part of it. This is absolutely necessary, of course, in the case of a hot-water system, but it is also advisable when steam is used; for although the air-vents on the radiators of a steam heating system are supposed to open and admit the air automatically when the radiators become cool, yet there is often some question about their efficiency in this respect, and hence it is advisable to open them up wide, by hand.

It is also exceedingly important to empty the boiler itself, particularly if it is made of wrought iron or steel, because a boiler of this kind is likely to become badly pitted if water is allowed to stand in it for a considerable time. Some authorities recommend that cast-iron boilers be left full of water during the summer; but if this plan is followed, care should be taken, in every case, to have the boiler entirely full, because it is far more likely to corrode if it is only partially filled. We strongly recommend emptying cast-iron boilers, however, as well as those made of wrought iron and steel.

The corrosive deterioration to which a heating boiler is likely to be subject during the summer months is by no means confined to its interior, for if the idle boiler is left full of water there will be considerable condensation upon its outer surface whenever warm, moist air comes in contact with it. This phenomenon is known as "sweating," and the moisture that is so deposited is likely to rust the boiler badly. If the boiler stands in a place which is naturally damp, and which cannot be kept dry by ventilation or otherwise, it may often prove advantageous to give it a coat of preservative paint.

When the boiler has been emptied, it should be cleaned out as well as possible, internally. Any scale or sediment that may have collected within it should be removed, although definite general directions for doing this cannot be given, because the best course to follow will vary to a large extent with the design of the boiler. Some heating boilers can be cleaned out fairly conveniently, while in others there is little or no provision made for internal cleaning. In heating boilers, however, the quantity of scale or sediment deposited is far less than in power boilers of like size, running with the same water. The loss of steam or water from heating boilers is small, and therefore, since but little water is fed to them while they are in service, there is also but a small amount of sediment or scale-forming matter introduced. In any case the boiler should be refilled and drained at least twice, after the water has been first run off from it, and it should be washed out with a powerful stream of water from a hose, when this is possible. When it has been emptied for the last time it should be allowed to drain very thoroughly, and any water that remains standing in it, after all has run off that will do so, should be removed by some other means.

When the boiler has been drained, the valve on the feed pipe should be examined to see if it is tight, and if there is any leakage at this point the valve should be repaired or replaced at once. The pipe through which the water is drawn off from the boiler should be left open so that if there should be any leakage from the supply pipe the water that so gains access to the boiler can flow out freely instead of accumulating inside of it.

The boiler should be opened up as completely as possible so that there may be a free circulation of air through it. If it has a manhole or handholes, these should be left open, and if the safety valve is of the lever type (as is usual on such boilers), it should be raised from its seat and fastened in the open position.

After the boiler has been thoroughly freed from water and opened up to the air, it is well to warm it a little for the purpose of drying off the moisture that still adheres to its inner surfaces. This operation should be performed with extreme care, and it is a serious mistake to entrust it to any but an intelligent and thoroughly reliable person. The boiler should *not* be warmed by building a fire upon the grate—even though very light materials are used—because there is danger of damaging it seriously in this way. The safe way to heat it is by placing a small, lighted, single-burner kerosene stove in the furnace, and leaving it there until it burns out. If the boiler becomes damp during the summer, it is well to repeat this operation at intervals whenever it seems desirable.

Some heating engineers favor placing a couple of pounds of unslaked lime ("quicklime") inside of the boiler to keep the air in it dry, the manhole, handholes and other openings being closed, in this case, sufficiently to prevent the air from entering freely from outside. If lime is used in this way it should not be placed directly upon the metal of the boiler, but should be held in a suitable receptacle—an earthenware dish being best for this purpose when it can be introduced into the boiler. If such a dish is used, however, care should be taken to see that it is removed in the fall before the boiler is restored to service again.

The outer surfaces of the boiler should be carefully cleaned and freed from soot and dust, and the spaces between the sections, if such sections exist, should also be cleaned out thoroughly in like manner. If evidences of external corrosion are visible, any rust or other deposit that may be found should be carefully removed by scraping or by the use of a scratch brush or otherwise, and after the corroded region has been thoroughly cleaned it should receive a preservative coating of red lead and oil or of some other equally efficacious preparation.

The soot and dust should be removed from all parts of the setting as well as from the boiler itself. The side walls should be brushed down, the grates should be cleaned and brushed, the ashpit should be well cleaned out and the smoke flue that leads to the chimney should be cleaned internally.

All the accessories of the boiler should be looked over carefully to see that they are in good working condition and ready for use the next season. The diaphragm that automatically regulates the dampers should be particularly examined to see that it is still soft and pliable, and its connections, including the dampers that it operates, should also be tested to see that they are in good order and that they work smoothly and easily. Any repairs or changes that are needed on the boiler or about the system elsewhere should be made as soon as possible after the boiler is put out of service. Early attention to these points is important, because the work is likely to be forgotten if it is delayed, or it may have to be done in the late fall when many other boilers are being returned to service and the repair men are so busy that it is hard to get them when they are wanted.

It is a common practice to throw waste papers and other light combustible things into the furnace of the heater during the summer months. This should be positively forbidden, and the furnace should be examined from time to time to see that the orders that have been given with regard to this point are respected. If papers and bits of wood are allowed to accumulate in the furnace it is highly probable that somebody will set fire to them during the summer. We recall one case in which an employee who was violating rules by smoking threw his lighted pipe into a furnace full of combustible rubbish when he heard his employer coming. The rubbish took fire and the empty boiler was badly damaged. No fire should be lighted under the boiler under any circumstances between the time it is laid up and the time it is made ready for service again in the fall.

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